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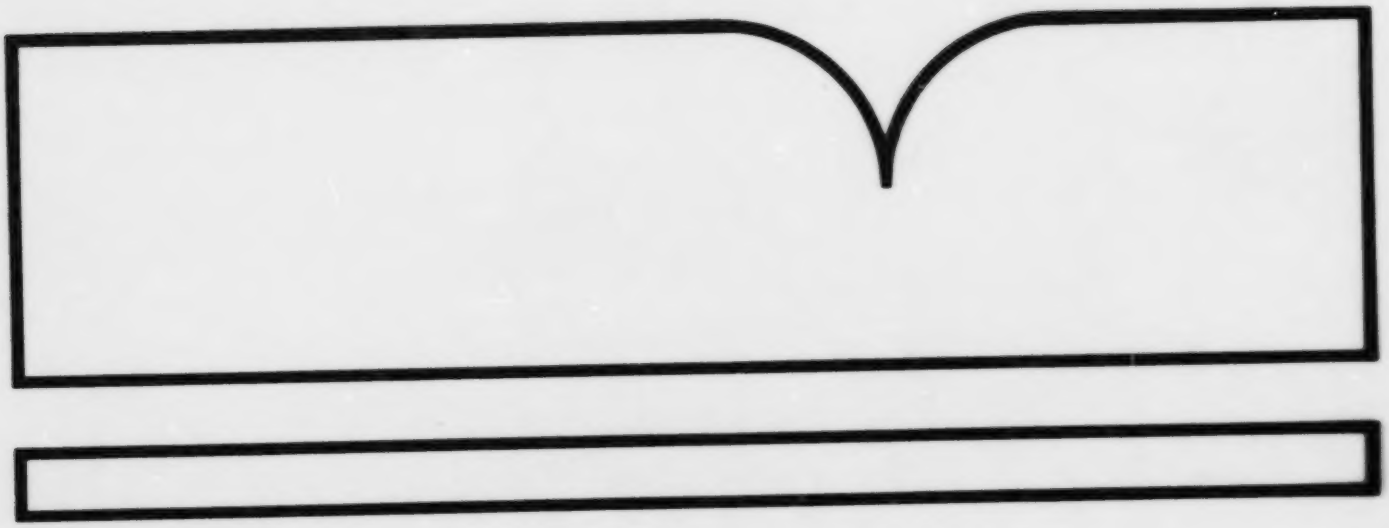

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COMMUNITY NOISE CONTROL:

MEASUREMENT AND REGULATION

PROCEEDINGS OF A CONFERENCE

TUCSON, ARIZONA

APRIL 9-10, 1980

Center for a Quiet Environment

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ABSTRACT

COMMUNITY NOISE CONTROL: MEASUREMENT AND REGULATION

A Conference Presented by: Center for a Quiet Environment,
University of California, Berkeley,
in cooperation with the Noise Control Program,
Region IX, U. S. Environmental Protection Agency,
and the State of Arizona Department of Health Services.

Tucson, Arizona
April 9-10, 1980

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INTRODUCTION TO NOISE AND ACOUSTIC TERMINOLOGY

by

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University of California, Berkeley

INTRODUCTION

The purpose of this introductory lecture is to familiarize conference participants with some basic ideas about physical acoustics and with the acoustical terminology which will be used by other speakers. It is necessarily technical, in part, but I have endeavored not to introduce unnecessary technical detail.

The presentation is in three parts. The first part deals with the physical nature of sound and its measurement and description. The second part describes some effects associated with the propagation of sound waves. The third part deals with human perception of sound and with measurement and description of human exposure to noise. (The words "sound" and "noise" are treated as synonyms; distinctions between them are highly subjective.)

The information contained here is not new. It has been gleaned from several sources; the four sources which I have found to be most helpful are listed below. Some of the figures are from the two EPA documents.

1. Public Health and Welfare Criteria for Noise, EPA Document No. 550/9-73-002.
2. Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety, EPA Document No. 550/9-74-004.
3. Noise and Vibration Control, edited by Leo L. Beranek, McGraw-Hill Book Co.
4. Handbook of Noise Measurement, 7th Edition, by Arnold P.G. Peterson and Ervin E. Gross, Jr., General Radio.

SOUND LEVELS AND SPECTRA

The three basic elements of an acoustical phenomenon are the source, the path and the receiver. The sound is generated at the source, usually by vibrational motion of a solid or by turbulent or pulsating flow of liquids or gases. These transmit a vibrational motion to the surrounding air, which then propagates as a sound wave through the air and other media. The acoustical energy may radiate equally in all directions from the source, or it may radiate in a highly directive manner. As the wave propagates it may combine with (or even be cancelled by) other sound waves and it may be reflected, refracted, scattered and absorbed. Usually it attenuates (diminishes in intensity) as it propagates away from the source, because its acoustical power is spread over an ever widening area and also because of reflection, scattering and absorption.

The vibrational motion of the air is accompanied by rapid fluctuations in the normal atmospheric pressure. This sound pressure is usually quite small (a sound pressure peak which is a factor 0.002 of normal atmospheric pressure is painfully intense) and the associated acoustical energy is also small. However, some explosive sounds carry considerably larger peak sound pressures.

The most important receiver, for our purposes, is the human ear, in which the vibrations are transduced to nerve impulses and transmitted to the brain. However, it may also be an electronic device such as a sound level meter, which displays an integrated measure of the sound pressure, or a tape recorder.

The physical characteristics of a sound wave are its amplitude (loudness or intensity) and its frequency content (pitch) and their variations

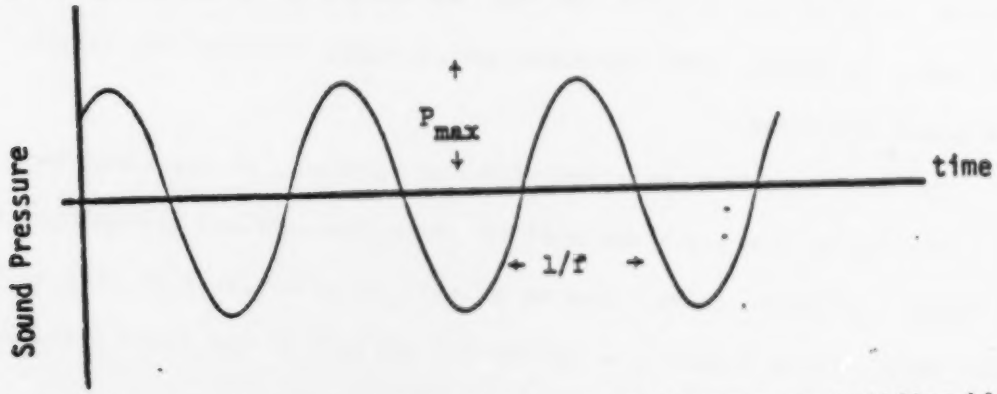
with time. Description of sound wave propagation effects, and analysis of the time-variations of amplitude and frequency, are deferred until later. Our immediate concern is with amplitude and frequency and these are best defined by consideration of a very simple sound wave called a pure tone.

PURE TONES

A pure tone is a sound wave with one frequency, and it is produced (to a good approximation) by a single piano note. The sound pressure (P) at a point varies sinusoidally with time (t):

$$P = P_{max} \sin 2\pi ft \quad .$$

The frequency f, which defines the rate at which the sinusoidal pattern repeats in time, and the amplitude P_{max}, which defines the peak sound pressure, fully describe the pure tone. The frequency measures pitch and the amplitude measures loudness, with increasing frequency corresponding to rising pitch and increasing amplitude to greater loudness.



Pure tones are quite important because they serve as building blocks in the sense that more complicated sounds can be represented as combinations of pure tones with different frequencies and amplitudes. This combination

may involve either a number of distinct frequencies (as in the case of a musical chord, or any periodic sound) or it may involve a continuous range of frequencies.

FREQUENCY

Frequency is measured in cycles per second (cps), which are also called Hertz (Hz). The normal human audible range is 16 Hz - 20 kHz* and the ear is most sensitive to sound in the neighborhood of 4 kHz. Sound with frequency below 16 Hz is called infrasound and sound with frequency above 20 kHz is called ultrasound.

It is sometimes convenient to partition the audible frequency range into frequency bands. Perhaps the most common partitioning is into octave bands. An octave is the range from any given frequency to twice that frequency. The center frequency of a band is the geometric mean of the upper and lower frequencies and it is twice the center frequency of the preceding octave band. The standard or preferred series of octave bands covers the audible range in ten bands, with center frequencies at

31.5 , 63 , 125 , 250 and 500 Hz

and 1 , 2 , 4 , 8 and 16 kHz.

The octave band centered on 1 kHz, for instance, extends from 707 Hz to 1414 Hz. Observe that the width of each octave band is a fixed percentage (approximately 70%) of its center frequency.

A finer partitioning is obtained by subdividing each octave band into three bands. These third-octave (or one-third-octave) bands also have constant percent band widths (approximately 23%). Other still finer part-

*one kiloHertz (kHz) equals 1000 Hz.

itionings are sometimes used (either constant percent band width, such as 1%, or constant band width, such as 10 Hz or 50 Hz) but the octave and third octave bands are most commonly used.

SOUND PRESSURE

It is conventional to describe the sound pressure amplitude by its root-mean-square (P_{rms}), which is the square root of the time-average of the square of the sound pressure. Usually the term "sound pressure" is used for "root-mean-square sound pressure".

The unit of pressure is either a microbar (μbar) which is approximately one millionth of normal atmospheric pressure, or a pascal or Newton per square meter (N/m^2), which equals ten microbars. The normal range of sound pressures extends from the threshold of audibility through the threshold of discomfort to the threshold of pain. The threshold of audibility for a pure tone is strongly frequency-dependent; approximate threshold pressures for a pure tone with frequency 1 kHz are

threshold of audibility	20 micropascals	(2×10^{-4} μbar)
threshold of discomfort	1 pascal	(10 μbar)
threshold of pain	200 pascals	(2×10^{3} μbar).

Two aspects of this pressure range should be noted; the pressures themselves are quite small but the range of values spans seven orders of magnitude (10^7).

SOUND PRESSURE LEVELS

This inconveniently large range of values of the sound pressure is reduced to a more manageable and meaningful scale by definition of the sound pressure level (SPL). A level is a relative measure defined as the logarithm

of the ratio of the value of a quantity to some reference value. For sound pressure levels the unit of measure is the decibel (dB) and the standard reference root-mean-square pressure (P_{ref}) is that corresponding to the normal threshold of audibility for a pure tone with frequency 1 kHz.

$$SPL = 10 \log_{10} \left(\frac{P_{rms}}{P_{ref}}\right)^2 \quad \text{dB re } P_{ref}$$

or

$$SPL = 20 \log_{10} \frac{P_{rms}}{P_{ref}} \quad \text{dB re } P_{ref}$$

with

$$P_{ref} = 20 \text{ micropascals.}$$

Since this reference pressure is standard it is not always stated explicitly. The normal sound pressure range, in decibels, is

threshold of audibility	0 dB
threshold of discomfort	110 dB
threshold of pain	140 dB

An additional advantage with use of the SPL is that the response of the ear is not directly proportional to the sound pressure. The assumption that the change in subjective response is proportional to the fractional change in stimulus suggests the use of a logarithmic scale and this is a reasonably good measure of the subjective response of the ear to different sound pressures. The decibel is a convenient unit because a change of 1 dB is about the minimum detectable change under laboratory conditions. A change of 3 dB is noticeable under normal conditions and a change of 6 dB is quite significant.

SOUND INTENSITY AND ENERGY

The sound intensity, which measures the power per unit area in a sound wave front, is an alternative measure of the amplitude of the wave. It is proportional to the square of the sound pressure and is usually measured in watts per square meter (watt/m^2). The sound intensity threshold values, for a pure tone with frequency 1 kHz, are:

(audibility) 10^{-12}watt/m^2 , (discomfort) 2.5×10^{-2}watt/m^2 , (pain) 10^{2}watt/m^2.

The range of values here is fourteen orders of magnitude and again the sound intensity level, in decibels, is the usual measure. It is so defined, with reference intensity 10^{-12}watt/m^2, that the numerical value of the sound intensity level is the same as that of the sound pressure level.

The sound energy density, which measures the energy per unit volume in a sound wave, is also proportional to the square of the sound pressure.

SOUND POWER

The sound pressure and sound intensity are characteristic of the sound wave amplitude at a particular location. An important characteristic of a source is its sound power (W), which is measured in watts and defines the rate at which the source radiates acoustical energy, under specified operating conditions. The sound power is not measured directly but is calculated from sound pressure measurements near the source in an appropriate test situation The sound power output of a source is usually described by the sound power level (SWL) in decibels, with standard reference power 10^{-12}watt:

$$SWL = 10 \log_{10} \frac{W}{W_{ref}} \qquad \text{dB re } W_{ref}$$

ACOUSTIC POWER AND SOUND POWER LEVELS OF TYPICAL NOISE SOURCES

Power	Power Level	Source
watts	dB re 10^{-12} watts	
100,000	170	Ram jet Turbojet engine with afterburner
10,000	160	Turbojet engine, 7000 lb thrust
1,000	150	4-propeller airliner
100	140	75-piece orchestra Pipe organ {Peak RMS levels in 1/8-second intervals
10	130	
3	125	Small aircraft engine
1.0	120	Large chipping hammer Piano {Peak RMS levels in 1/8-second intervals BB^b tuba
0.1	110	Blaring radio Centrifugal ventilating fan (13,000 CFM)
0.01	100	4' loom Auto on highway
0.001	90	Vanaxial ventilating fan (1500 CFM) Voice – shouting (average long-time RMS)
0.0001	80	
0.00001	70	Voice – conversational level (average long-time RMS)
0.000001	60	
0.0000001	50	
0.000,000,01	40	
0.000,000,001	30	Voice – very soft whisper

* Space Average Sound Pressure Level at 10 Meters = Power Level - 28 dB

or

$$SWL = 120 + 10 \log_{10} W \qquad \text{(W measured in watts)}.$$

It is interesting to note that the fraction of the mechanical energy of a machine which radiates as acoustical energy is usually quite small. The ratio of the sound power to the mechanical power ranges from less than 10^{-6} (1 ppm) for quiet electrically powered machinery to 10^{-3} (1000 ppm) for the noisier jet aircraft.

SPECTRUM ANALYSIS

The frequency content of a sound is described by specifying the distribution of sound pressure as a function of frequency. This is usually done by partitioning the frequency range and specifying the sound pressure level (SPL) for each band. This representation of the sound is called a spectrum (octave band spectrum, third-octave band spectrum, etc.) and the instrument which allows measurement of sound spectra is called a sound wave analyzer.

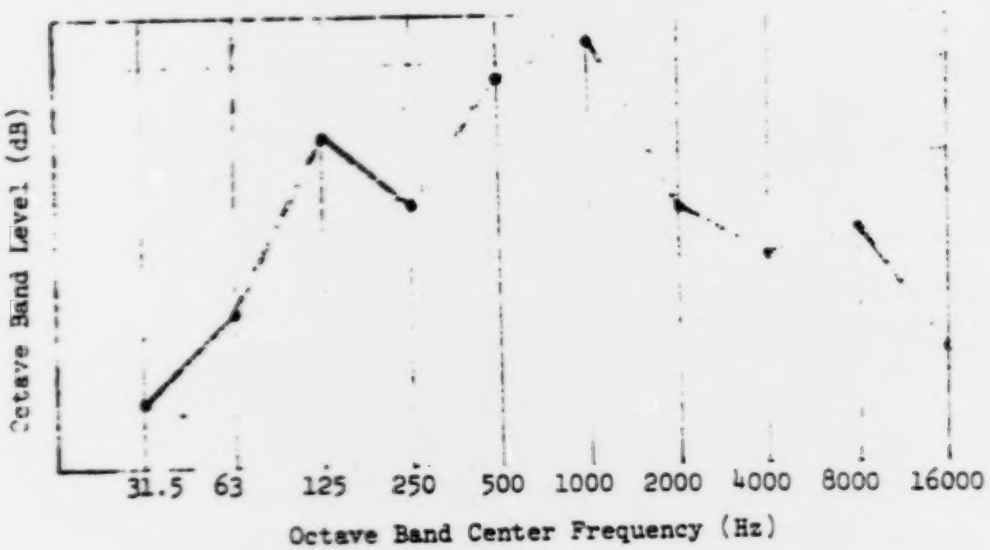
The spectrum is an important descriptor for most types of sound. Broadband noise has energy distributed over a broad range of audible frequencies and narrowband noise has a narrow frequency spectrum (less than one-third octave) which may be located anywhere in the audible range. Sometimes a broadband noise has pure tone or narrowband component, that is a spectrum in which the level at or near a particular frequency is significantly greater than the levels of adjacent frequencies. Identification of such components (which add greatly to the "noisiness" or unacceptability of the sound) requires a reasonably fine frequency analysis.

Three types of noise which are used in technical acoustics are white

noise, pink noise and red noise. Their spectra are such that for any constant percent bandwidth partitioning the white spectrum level increases by 3 dB for each doubling of band-center frequency, the pink spectrum level is constant and the red spectrum level decreases by 3 dB. Thus, the white noise has considerable high frequency content while the red noise has very little high frequency content.

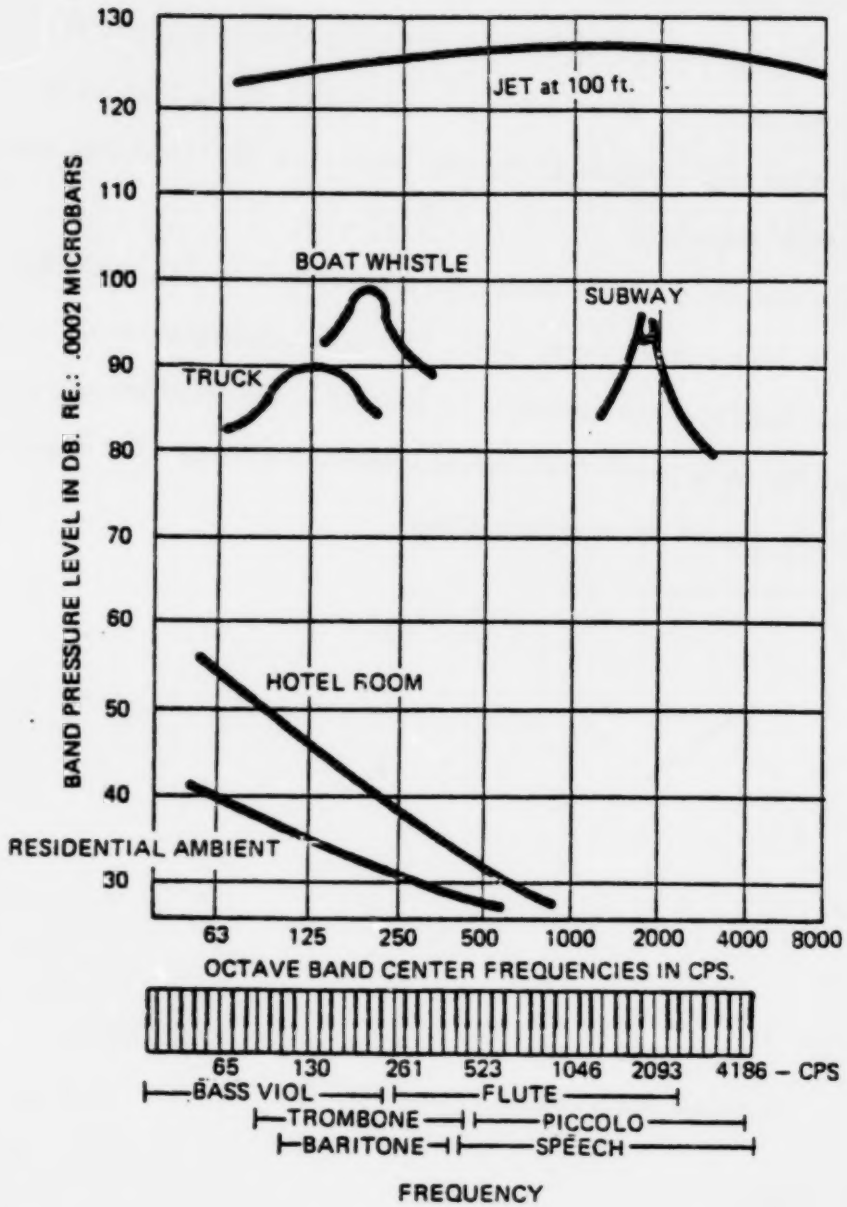
The frequency content of a source is also described by its spectrum, which specifies the sound power level (SWL) for each frequency band.

The graphical display of a spectrum is usually a representation of the band levels as points on a level (dB) versus center frequency (Hz) mesh, with adjacent points joined by straight lines.



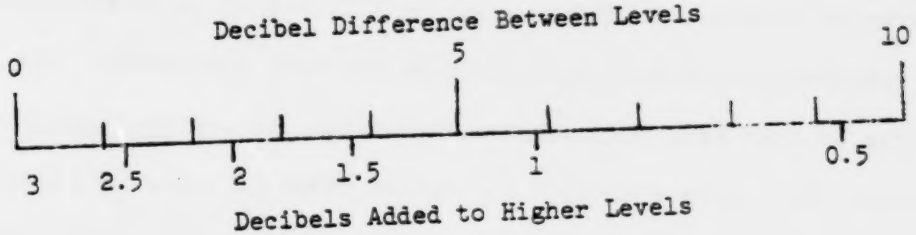
COMBINATION OF SOUNDS

For various reasons one must know how to "add decibels". Most importantly, one may wish to calculate the total sound, at a given location, due to the combination of sounds from two or more sources. Or, one may wish to compute the total sound power of a source when the third-octave band spectrum is known, or to calculate the total sound energy for an extended period of



Typical noise spectra

time when the sound pressure history is known. The important point is that, for practical purposes, sounds are combined on an energy basis rather than on a pressure basis. The resultant sound energy is found by adding the component energies; the resultant sound pressure is not found by adding the component pressures. Thus, given two SPLs one must calculate the corresponding squared sound pressures, add them and compute the associated SPL. The resulting formula is rather complicated but is shown effectively by the following scale:



Observe that the combination of two sounds with the same SPL leads to an increase of 3 dB. It follows that halving the sound power of a source leads to a reduction of only 3 dB in the SPL at any location. Thus, a considerable reduction in sound energy is required to bring about a significant decrease in the noise; for instance a 10 dB decrease requires an energy reduction of 90%.

Observe too that the combination of two sounds with different SPLs adds less than 3 dB to the larger SPL. If the two SPLs differ by more than 10 dB then the level of the quieter sound has no appreciable effect on the total level. The following rule-of-thumb is generally accepted: If the sound pressure levels, when a source is operating, exceed the ambient levels by 10 dB or more in all octave bands, then the contribution of the ambient noise is negligible and the measured levels are essentially due to the source.

PROPAGATION OF SOUND

As a sound wave propagates it diminishes in intensity due to spreading of the wave front and due to absorption in the air and in other media. It is scattered by small obstacles, diffracted around rigid barriers, reflected from and transmitted through solid structures and refracted (changed in direction) due to wind and temperature gradients in the air.

The different frequency components may be affected in different ways, so that the spectrum of the wave may change as the wave propagates. The reason for this is that each frequency component has its own wavelength λ, which defines the distance between successive pressure peaks in a plane or spherical pure tone wave. The wavelength is related to the sound speed c and to the frequency f by

$$c = \lambda f \quad .$$

The sound speed in air is approximately 340 meters per second or 1100 feet per second, independently of the frequency, and so the higher frequency components have shorter wavelengths. The wavelengths for audible pure tones range from 20 meters (23 yards) at 16 Hz to 1.7 centimeters (0.66 inches) at 20 kHz. Thus, it is not surprising that sound waves are scattered by leaves, diffracted by a six foot barrier or transmitted through a one inch panel in a manner which depends on the wavelength and hence on the frequency.

GEOMETRICAL ATTENUATION

One of the more important aspects of sound wave propagation is the geometrical attenuation due to spreading of the wave front. For an isolated source the sound intensity integrated over a spherical surface sur-

rounding the source equals the sound power output of the source, if air absorption is neglected. Consequently, the sound intensity is inversely proportional to the square of the distance from the source and the SPL decreases by 6 dB with each doubling of distance from the source, due to the geometrical attenuation. This is true regardless of whether or not the radiation from the source is directional. When the source is close to the ground, the first effect of the ground is to act as a baffle, i.e., to double the effective sound power of the source since the radiation now occurs over a hemisphere instead of a sphere. The 6 dB attenuation rule (also called the inverse square rule) still applies.

For a line source (such as a steady stream of traffic) the radiation pattern reasonably close to the source is a spreading over a cylindrical (or hemicylindrical) front. Consequently, the SPL decreases by only 3 dB with each doubling of distance from the source. Again, the baffle effect of the ground doubles the effective power output of the source.

GROUND EFFECTS

In addition to the geometrical attenuation, outdoor noise also attenuates due to absorption by the ground. This ground absorption depends on the ground covering and on the heights of the source and receiver. Some anomalous effects are observed, especially in the frequency range below 600 Hz, due to mixing of direct and reflected waves. Thus, strictly speaking, the ground attenuation should not be stated simply as an SPL decrease per unit distance. Nevertheless, the following curves give reasonably good approximations of the effects of various types of ground cover. It is evident that trees are not particularly effective as acoustic shields.

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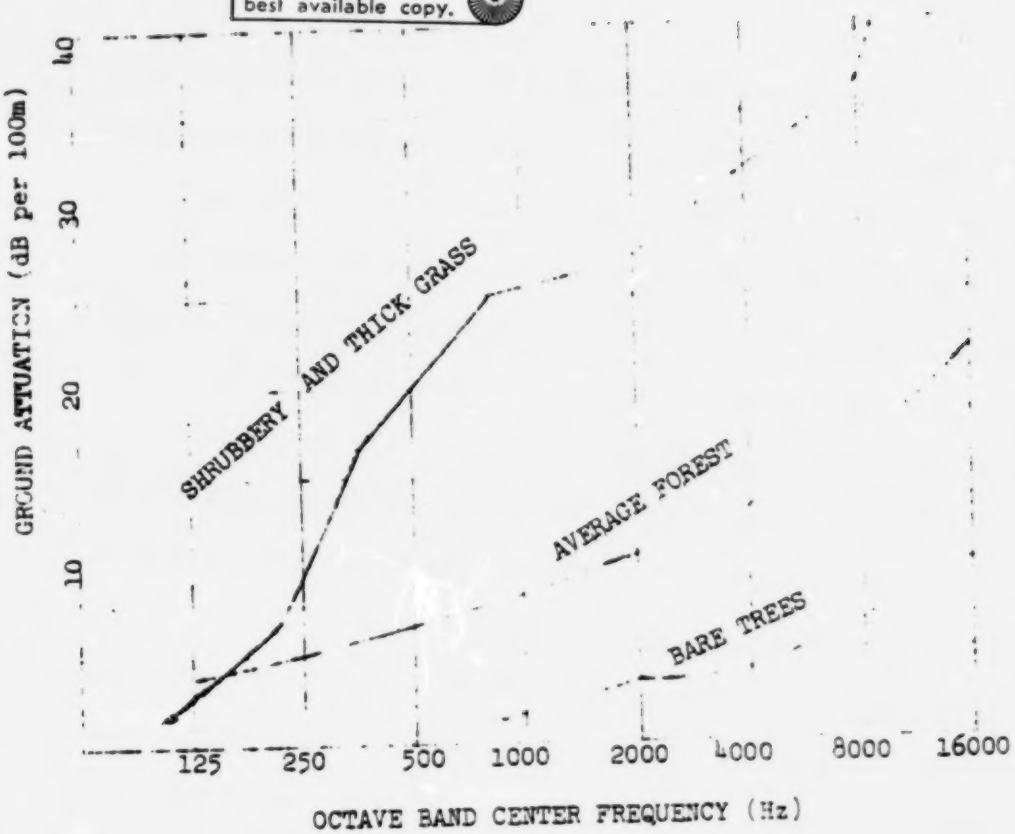

A quite different ground effect is ground vibration. This will transmit vibrations from a railway, for example, through the ground to adjacent buildings. The resulting structural vibrations of the buildings will then generate noise, usually a low-frequency rumbling.

ABSORPTION IN AIR

Attenuation due to absorption in the air is generally unimportant for propagation distances less than 100 m. It can be of some importance in dealing with aircraft noise. The attenuation increases with relative humidity but additional corrections due to fog, rain or snow are not significant. Higher frequencies are attenuated much more strongly than lower frequencies. With relative humidity of 60%, the approximate attenuation

rates, in decibels per 100 meters, for white noise (which has greatest high frequency content), pink noise and red noise are 3 dB/100m, 0.7 dB/100m and 0.07 dB/100m.

BARRIERS

When a sufficiently heavy barrier wall is interposed between source and receiver, the sound reaches the receiver only by diffraction around the boundaries of the wall. The formula for the resulting noise reduction is rather complicated and depends on the nature of the source (point source, line source), on the location of source and receiver, and on the frequency of the sound. A reduction of about 25 dB is obtained for high frequency noise, when both source and receiver are reasonably close to the barrier and this decreases when the frequency is reduced, or when source or receiver move further from the barrier. The nosie reduction may be enhanced by lining the source side of the barrier wall with sound absorbing material.

Buildings interposed between source and receiver have a similar attenuation effect on traffic noise in urban areas. Measurements indicate that the reduction is between 15 dB and 20 dB and that this is apparently independent of the number of intervening rows of buildings; the first row serves as the barrier and subsequent rows do not have a significant effect.

TRANSMISSION LOSS

The sound-insulating capability of a wall or panel is described by its transmission loss (TL) in decibels, which measures the drop in sound pressure level from the source side to the receiver side of the wall or

panel. The transmission loss varies with frequency and the sound insulation is more effective at higher frequencies. It is especially poor near the critical frequency of the wall, which is usually in the lower frequency range.

The sound insulating capability of a composite panel, such as a wall with windows (open or closed) or a panel with an open vent, is quite interesting. Suppose, for instance, that a sound insulating panel has an open gap whose area is 10% of the total area. Then it does not matter very much how effective the panel is; the presence of the gap reduces the TL from any value of 15 dB or more down to 10 dB. Even a 1% gap reduces the TL from any value of 25 dB or more down to 20 dB. The following TL values for houses of light frame and of masonry are interesting in this regard:

Type of Structure	Windows Open	Windows Closed (Single-Pane)	Windows Closed (Double-Pane)
Light Frame	10 dB	20 dB	30 dB
Masonry	10 dB	25 dB	35 dB

REFRACTION

Refraction is a bending of the wave propagation path which usually occurs in outdoor sound propagation due to either wind velocity gradients or temperature gradients. Usually the wind velocity increases with height and this causes sound waves travelling downwind to curve downwards and those travelling upwind to curve upwards. Similarly, the temperature dependence of the sound speed in air causes waves to bend upwards when temperature decreases with height and to bend downwards when the temperature

increases with height (this latter effect accounts for the enhanced sound propagation across a cool lake). Refraction effects are not especially important in environmental noise control although they do give rise to some significant effects for regions with prevalent wind patterns or frequent temperature inversions.

REVERBERATION

Reverberation due to multiple reflections is an important aspect of sound wave propagation in enclosed spaces such as auditoria, offices, dwellings, tunnels and ducts. It has been estimated, for instance, that seven eights of the sound which reaches a listener in a concert hall has been reflected from the ceiling, walls or floor, and this gives the sound its live, resonant quality. The simplest description of the acoustical response of a room is its reverberation time, which is a measure of the decay time of sound in the room. It ranges from practically zero in anechoic chambers to several seconds in reverberation chambers. Typical reverberation times for rooms which are designed primarily for speech range from less than one-half second to one second. Excessive reverberation leads to masking and interference with speech communication. Reverberation times for auditoria may be as long as two seconds or more.

A more detailed study of reverberant sound leads to a consideration of the standing wave patterns and of the frequency response of the enclosure. It is seen, for example, that the sound pressure levels due to a sound source with given sound power level will depend on the location of the source in the enclosure. Knowledge of the standing wave patterns also facilitates effective noise reduction by use of sound absorbing materials.

HUMAN EXPOSURE TO NOISE

The discussion thus far has focused on objective physical description of the sound measured at a particular time. However, the human perception of sound is not objective and the human response to sound depends, to a considerable extent, on the manner in which the sound varies with time.

Environmental noise at a particular location will usually vary quite markedly with time. The variations may be intermittent single-event disturbances of a quiet and steady residual noise level, as in a residential suburb with occasional traffic, aircraft flyovers and mowing of lawns. Or, the noise level may be consistently high, as in an urban location with continuous noise from street or freeway traffic and construction, industrial, commerical and recreational activities. Some types of noise may be particularly annoying, notably noise with a significant pure tone component (whine, screech or buzz) and repeated impulsive noise*, such as hammering, riveting, typewriting or pile driving. The degree of annoyance and interference with speech, sleep or work caused by intrusive noise depends on its duration, character (pure tones, repeated impulses) and relation to the residual noise level.

The subjectivity of the human perception of sound is simply and adequately accounted for by use of response weighting networks (which model the ear's response) in measuring sound levels. A simple and adequate accounting for the effects of the duration and character of the sound is a more difficult task. For some purposes, such as specifying acceptable limits in a noise ordinance, it may be sufficient to include specified

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* Impulsive noise has short duration (a fraction of a second) and a rapid rise to the peak pressure, which is often extremely high.

adjustments of the limits (in decibels) to account for the duration and pure tone or impulsive character of the intrusive noise, and for its relationship to the residual noise level.

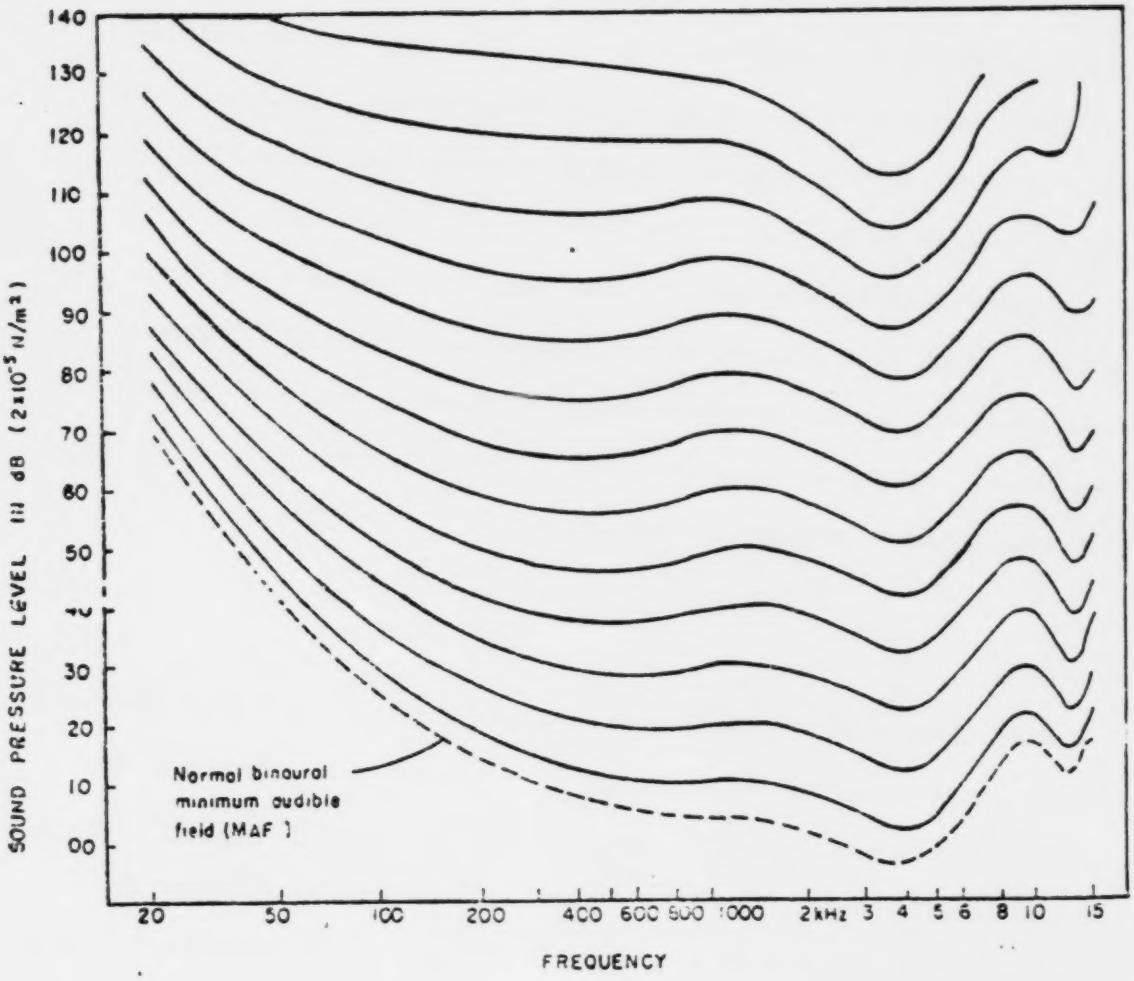
There are two common approaches to cumulative measurement of noise exposure. One involves statistical analysis of the sound levels during the period of interest and the other involves definition of single-number integrated measures of exposure. Several such single-number measures have been introduced and they correlate reasonably well with each other and with measures of community response to noise. Unfortunately, they tend to require rather complicated data reduction and analysis.

A comprehensive treatment of these topics is beyond the scope of this lecture. There is a discussion of the human perception of "loudness" and "noisiness" and of the important response weighting networks (notably the A-weighting) which take account of them. Finally, some of the more important single-number ratings and statistical levels are discussed.

LOUDNESS

Pure tones with the same sound pressure level and different frequencies are not rated by humans as being equally loud. This is especially true at lower sound pressure levels, as evidenced by the equal loudness contours for pure tones, based on psychoacoustical experiments by Fletcher and Munson and more recently by Robinson and Dadson. Equal loudness contours for narrow band random noise are quite similar to those for pure tones.

The equal loudness contours identify loudness levels, measured in phons , for pure tones or for narrow band noise. Phons correspond to SPL decibels at frequency 1 kHz, so that the equal loudness curve passing through the 60 dB level at 1 kHz, for instance, identifies the loudness



Normal Equal-loudness Contours for Pure Tones

level 60 phons. Further investigations of the perceived loudness ratio of sounds (twice as loud, half as loud, etc.) indicate that an increase of 10 phons corresponds to a doubling of the perceived loudness. This leads to a loudness measure in sones. The loudness level 40 phons is taken as 1 sone, the level 50 phons as 2 sones (twice as loud), and so on. The relation between the loudness in sones (S) and the loudness level in phons (L) is

$$S = 2^{(L-40)/10} .$$

Procedures have been developed by Stevens and by Zwicker for calculating perceived loudness, or loudness level, from octave band or third-octave band spectrum levels.

NOISINESS

Ratings of noisiness (or intrusiveness or unacceptability) of sounds differ from loudness ratings. These differences are not very significant for pure tones or narrow band noise and the equal noise contours are similar to the equal loudness contours. The perceived noise level (PNL) in decibels (PNdB) and the noisiness (measured in noys) are defined analogously to the loudness level and the loudness. For more complicated sounds the ratings of loudness and noisiness may differ quite markedly. Kryter has identified the five physical aspects of a sound which are most likely to control its perceived noisiness as (1) spectrum content and level (2) spectrum complexity (pure tone or narrowband concentrations) (3) total duration (4) rise time to peak amplitude for non-impulsive sounds and (5) increase in level, during 0.5 sec or less, for impulsive sounds. Procedures for calculating the perceived noise level from octave-band or

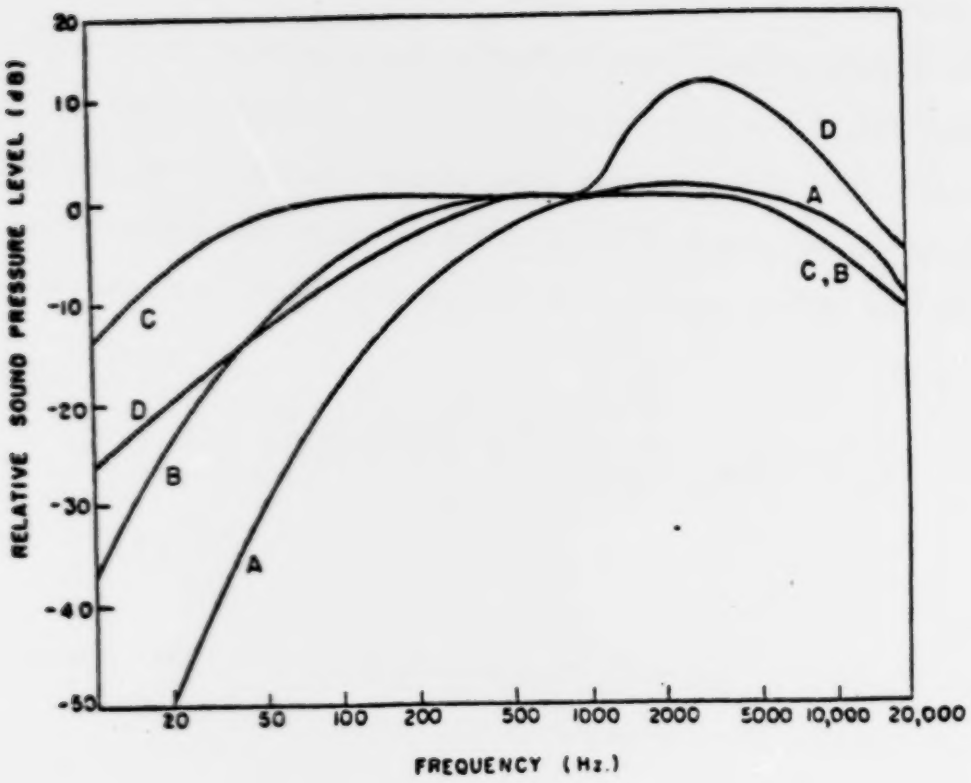
third-octave band spectra are available.

WEIGHTED LEVELS

The frequency dependence of the human rating of loudness is taken into account in noise measurements through the use of response weighting networks. Most sound level meters have three or more such networks in addition to the flat SPL measure. The A-weighting network electronically weights the various frequencies in accordance with the 40 phon Fletcher-Munson contour and then sums the weighted spectrum to obtain the A-weighted sound pressure level (dBA). Thus, it approximates the human sensititvity to sounds of low intensity. The B-weighting network is based on the 70 phon Fletcher-Munson contour and it approximates the human sensitivity to sounds of medium intensity. The C-weighting network is essentially flat over most of the audible range but drops off at high and low frequencies and it approximates the human sensitivity to sounds of high intensity.

The A-weighting network is by far the most important and sound pressure levels in dBA are widely used in noise control. The B-weighting network is rarely used and the C-weighting network is used occasionally instead of the flat response, to diminish the effect of frequencies outside the audible range, or together with the dBA level measurement to obtain more information about the spectrum.

Various other weighting networks have been proposed and, in particular, the D-weighting network, based on the 40 noy (or 94 PNdB) equal noisiness contour, is available on some more recent sound level meters.



EQUIVALENT AND DAY-NIGHT SOUND LEVELS

The human response to noise exposure depends not only on the amplitude of the noise and on its frequency content but on many aspects of the variation of these quantities with time. A detailed accounting for the many factors which influence the human response would require a very complicated methodology and measurement technology. The EPA Levels Document lists seven requirements in its choice for measurement of environmental noise and concludes that "the magnitude of sound is of most importance insofar as cumulative noise effects are concerned. Long-term average sound level,

henceforth referred to as equivalent sound level (L_{eq}), is considered the best measure of environmental noise to fulfill the above seven requirements".

The magnitude of sound referred to here is the A-weighted sound pressure level. The equivalent sound level is the A-weighted sound pressure level of the steady continuous noise which has the same total sound energy as the actual fluctuating noise for the time interval under consideration. It is defined by

$$L_{eq} = 10 \log_{10} \left[\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} 10^{\frac{1}{10} SPL(t)} dt \right] ,$$

where t_1 and t_2 are the times at the beginning and end of the time interval and SPL(t) is the A-weighted sound pressure level at time t.

EQUIVALENT SOUND LEVELS IN DECIBELS NORMALLY OCCURRING INSIDE VARIOUS PLACES

SPACE	L_{eq}(+)
Small Store (1-5 clerks)	60
Large Store (more than 5 clerks)	65
Small Office (1-2 desks)	58
Medium Office (3-10 desks)	63
Large Office (more than 10 desks)	67
Miscellaneous Business	63
Residences	
Typical movement of people—no TV or radio	40-45
Speech at 10 feet, normal voice	55
TV listening at 10 feet, no other activity	55-60
Stereo music	50-70

(+) These measurements were taken over durations typical of the operation of these facilities.

Three particular versions of the equivalent sound level are used in the Levels Document:

1. The L_{eq} for an 8-hour period ($L_{eq(8)}$) to serve as a basis for identifying environmental noise which causes damage to hearing.
2. The day-night sound level (L_{dn}) to relate noise in residential environments to chronic annoyance by speech interference* and in some part by sleep and activity interference. It is defined as the A-weighted average sound level for a 24-hour period with a 10 dB weighting applied to night-time (10 p.m. - 7 a.m.) sound levels.
3. The L_{eq} for a 24-hour period ($L_{eq(24)}$) to relate to long-term health and welfare effects of noise.

The mathematical definition of the day-night sound level is

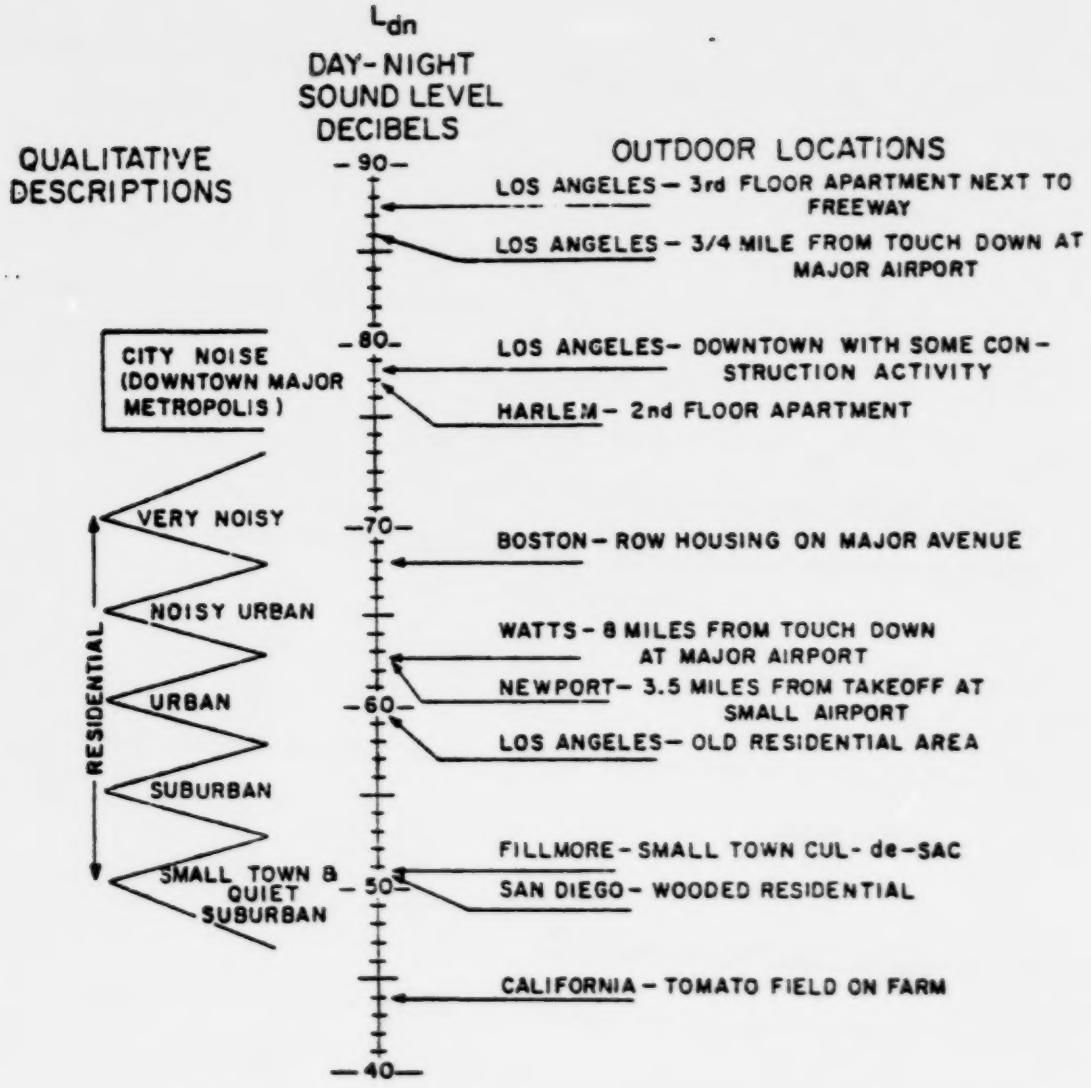
$$L_{dn} = 10 \log_{10} \left[\frac{15}{24} \left(10^{L_d/10}\right) + \frac{9}{24} \left(10^{(L_n+10)/10}\right)\right] \text{ dB}$$

where L_d and L_n are the equivalent sound levels for the day and night periods, respectively.

OTHER CUMULATIVE MEASURES OF EXPOSURE

Other weighted cumulative measures of noise exposure, which are currently used by federal agencies, include the following:

*An alternative measure of the speech interference effect is the Preferred Speech Interference Level (PSIL). This takes account of the fact that the masking of one sound by another is most effective when their frequency contents are similar. The PSIL is simply the arithmetic mean of the sound pressure levels (SPL in dB) for the octave bands centered on 500 Hz, 1000Hz and 2000Hz.


L_{dn}
DAY-NIGHT SOUND LEVEL DECIBELS
QUALITATIVE DESCRIPTIONS
OUTDOOR LOCATIONS
90
80
70
60
50
40
LOS ANGELES – 3rd FLOOR APARTMENT NEXT TO FREEWAY
LOS ANGELES – 3/4 MILE FROM TOUCH DOWN AT MAJOR AIRPORT
CITY NOISE (DOWNTOWN MAJOR METROPOLIS)
LOS ANGELES – DOWNTOWN WITH SOME CONSTRUCTION ACTIVITY
HARLEM – 2nd FLOOR APARTMENT
RESIDENTIAL
VERY NOISY
NOISY URBAN
URBAN
SUBURBAN
SMALL TOWN & QUIET SUBURBAN
BOSTON – ROW HOUSING ON MAJOR AVENUE
WATTS – 8 MILES FROM TOUCH DOWN AT MAJOR AIRPORT
NEWPORT – 3.5 MILES FROM TAKEOFF AT SMALL AIRPORT
LOS ANGELES – OLD RESIDENTIAL AREA
FILLMORE – SMALL TOWN CUL-de-SAC
SAN DIEGO – WOODED RESIDENTIAL
CALIFORNIA – TOMATO FIELD ON FARM

Examples of Outdoor Day-Night Sound Level in dB (re 20 micropascals)

1. Composite Noise Rating (CNR) is used mainly for evaluating land use around airports. Thus, the noise environment is one of intermittent single events superimposed on a steady residual noise, the single events being so intense that they usually dominate any cumulative measure of noise exposure. The CNR method rates each single event by its maximum perceived noise level (PNL_{max}), that is the peak value (in PNdB) of the PNL. It averages these maximum values, on an energy basis, and takes account of the number of single events in such a way that each night event per hour is equivalent to ten events per hour during the day. The day and night periods are the same as for L_{dn} and so each night event is equivalent to almost 17 events during the day. The differences between CNR and L_{dn} are (a) the use of PNL_{max} rather than SPL and (b) the nightime level weighting is approximately 12 dB rather than 10 dB.

2. Noise Exposure Forecast (NEF) is a modification of the CNR which rates each single event by its equivalent perceived noise level (EPNL) instead of its PNL_{max}. The EPNL is a time-averaged loudness level with a pure tone correction, so that it accounts for the duration and frequency content of the event as well as for its amplitude.

3. Community Noise Equivalent Level (CNEL) is essentially the same as L_{dn} except that it breaks the 24-hour period into day (7 a.m. - 7 p.m.), evening (7 p.m. - 10 p.m.) and night (10 p.m. - 7 a.m.) and weights the evening and night levels by 5 dB and 10 dB, respectively. The related single-event noise exposure level is called the SENEL.

Approximate methods are given in the EPA Levels Document for calculating

FACTORS CONSIDERED IN EACH OF FOUR METHODS FOR DESCRIBING THE INTRUSIVENESS OF NOISE ON THE COMMUNITY

FACTOR	COMPOSITE NOISE RATING	NOISE EXPOSURE FORECAST	DAY/NIGHT AVERAGE SOUND LEVEL	COMMUNITY NOISE EQUIVALENT LEVEL
Basic Measure	Maximum Perceived Noise Level	Tone Corrected Perceived Noise Level	A Weighted Noise Level	A Weighted Noise Level
Measure of Duration of Individual Single Event	None	Energy Integration	Energy Integration	Energy Integration
	day 7 a.m. - 10 p.m. night 10 p.m. - 7 a.m.			day 7 a.m. - 7 p.m. evening 7 p.m. - 10 p.m. night 10 p.m. - 7 a.m.
Weighting for Time Period	Day 0 dB Night 12 dB		Day 0 dB Night 10 dB	Day 0 dB Evening 5 dB Night 10 dB
Number (N) of Identical Events in Time Period	10 Log N		10 Log N	
Summation of Contributions	Logarithmic		Logarithmic	

L_{dn}, CNR, NEF and CNEL in situations when the single event noises are of sufficient magnitude, relative to the background noise, that they control the cumulative measure. While there is no fixed relationship between the four measures, under such circumstances the relations

$$L_{dn} \simeq \text{CNEL} \simeq \text{NEF} + 35 \simeq \text{CNR} - 35$$

are usually valid to within ±3 dB.

SUMMARY OF NOISE LEVELS IDENTIFIED AS REQUISITE TO PROTECT PUBLIC HEALTH AND WELFARE WITH AN ADEQUATE MARGIN OF SAFETY

EFFECT	LEVEL	AREA
Hearing Loss	$L_{eq(24)} \leq 70$ dB	All areas
Outdoor activity interference and annoyance	$L_{dn} \leq 55$ dB	Outdoors in residential areas and farms and other outdoor areas where people spend widely varying amounts of time and other places in which quiet is a basis for use.
	$L_{eq(24)} \leq 55$ dB	Outdoor areas where people spend limited amounts of time, such as school yards, playgrounds, etc.
Indoor activity interference and annoyance	$L_{dn} \leq 45$ dB	Indoor residential areas
	$L_{eq(24)} \leq 45$ dB	Other indoor areas with human activities such as schools, etc.

STATISTICAL LEVELS

The fluctuations in sound level at some location during a specified

period of time may also be described by the level distribution. The decibel range is partitioned, for example into 2 dB intervals, and the level distribution or fraction of the total time for which the sound level lies in each interval may be plotted as a histogram. An alternative display is a cumulative distribution of sound levels; that is, a curve indicating for what percentage of the total time each sound level is exceeded.

This complete detail is rarely needed, but the particular levels L_1, L_{10}, L_{50}, L_{90} and L_{99}, which define the levels which are exceeded 1,10, 50, 90 and 99 percent of the time, are commonly used. The L_1 is representative of the high level, short duration noise but it should be used with some caution. It does not give any indication of the extent by which this level is exceeded, only that it is exceeded for 1% of the total time, and so it may not be at all indicative of the peak levels. Similarly, the L_{10} for highway noise is virtually unaffected by the noise from diesel trucks. The L_{50} defines the median level but it may differ greatly from the energy mean level L_{eq}. In fact, the L_{eq} is usually closer to the L_{30}. The L_{90} or L_{99} are often chosen as representative of the residual noise level.

COMMUNITY RESPONSE TO NOISE:
HEALTH EFFECTS AND SUBJECTIVE REACTION

Presented by:
Jim Buntin
Director, Center for a Quiet Environment
April 9-10, 1980
Tucson, Arizona

I. HEALTH EFFECTS

A. HEARING LOSS

There are two major types of hearing loss: conductive and sensori-neural. A conductive loss is usually associated with the outer or middle ear. This kind of loss is usually caused by a perforation or infection in the middle ear or an inflammation of the middle ear bones. This loss blocks transmission of sound to cochlea or inner ear. Conductive losses are correctable by surgery. A sensori-neural loss results from damage to the cochlea or neural structures of the ear. Birth defects, noise, ototoxic drugs, fever, or trauma may cause this type of loss. Sensori-neural losses are not medically correctable. In addition, sensori-neural hearing loss can be classified in several ways: noise-induced, presbycusis, sociocusis, or due to birth defects, congenital problems, disease, injury, or drugs.

Conductive hearing loss can be caused by noise. Rupture of the ear drum and disturbance of the middle ear bones can result from a very high amplitude impulse or blast. This is often called traumatic hearing loss. The maximum degree of a conductive loss is usually around 55 to 60 dB.

Common causes of sensori-neural hearing loss in newborn babies: most babies born with hearing impairments have sensori-neural hearing losses. These can be either congenital (genetically inherited from the parents) or due to damage to embryo in utero. Certain diseases such as rubella (German measles) or influenza that the mother contracts during pregnancy can result in sensori-neural hearing loss as a birth defect in the child.[1]

Diseases such as measles, mumps, scarlet fever, diphtheria, whooping cough, influenza, and certain other viral infections can lead to sensori-neural hearing loss. The processes of these diseases can have a toxic effect on the sensitive nerve endings in the cochlea. Infections of the cerebrospinal fluid such as meningitis can also cause damage to the cochlea. Tumorous growth near the auditory nerve can cause sensori-neural hearing loss due to pressure on the nerve.[2]

1. Noise-Induced Permanent Threshold Shift (NIPTS)

NIPTS is a permanent shift in the hearing threshold (a lowering of the sensitivity) of the ears due to exposure to noise. It is sensori-neural type of hearing loss, and is not reversible.[3] NIPTS can result from either a single exposure to high intensity impulsive noise such as blasts or explosions, or to longer exposures to lower, but still damaging noise levels. Typically, hearing loss due to noise exposure occurs first at the higher frequencies, particularly around the 4000 Hz level (3000 - 6000 Hz).[4]

2. Presbycusis

Presbycusis is a hearing loss associated with increasing age. It is most marked at higher frequencies, especially those above 3000 Hz. The causes of presbycusis are believed to be deterioration of the central nervous system and changes in the auditory system.[5]

3. Sociocusis

Sociocusis is noise-induced permanent threshold shift (loss of hearing sensitivity) attributed to environmental noise (hearing loss from non-occupational noise exposure).[6] It is difficult to separate sociocusis from hearing loss due to aging (presbycusis) or to occupational noise exposure. Exposures to high levels of environmental noise may accelerate loss normally due to aging.[7]

Due to our complex, noisy environment it is difficult, if not impossible, to separate hearing loss due to aging from noise-induced hearing loss, both from occupational and environmental noise. Few people live their whole lives in quiet surroundings. Almost everyone suffers some exposure to damaging noise; either at home, at work, at leisure, or during transportation between these activities. Some researchers contend that presbycusis consists mainly of hearing loss due to lifetime exposure to the aggregate of noise found in the environment. Another view states that environmental noise only accelerates the losses at high frequencies that would have occurred anyway through aging.[8]

Rosen conducted a study of the primitive Mabaans of the African Sudan. Their environment was almost free of noise with a typical background level of 40 dB (A-weighted). Among the Mabaans, the hearing abilities of men in their seventies and eighties is equal to that of healthy children at age ten.[9]

These findings suggest that the Mabaans show little if any hearing loss due to aging (presbycusis). The implication of these findings is that much of the hearing loss observed with age in industrial countries could be due to environmental noise exposure (sociocusis) rather than aging (presbycusis). Rosen's findings may be attributable to diet or other causative factors.

4. Physiological basis

The following mechanisms are considered to play a role in causing damage to the sensory cells of the inner ear:

Destruction of cochlear tissue because of the physical force of the sound pressure,

Cardiovascular factors resulting from diminished blood supply to the cochlea during noise exposure,

Alteration of fluid transport across Reissner's membrane during noise exposure,

Alteration of biochemical processes during noise exposure.[10]

The hair cells normally convert the mechanical energy of sound vibrations into neuro-electrical signals that are transmited to the brain. As the intensity of the noise or the time for which the ear is exposed is increased, a greater proportion of the hair cells are damaged or destroyed.

To illustrate the sensitivity of the human ear, note that the lower audible limit of particle displacement occurs near 3900 Hz, when the excess sound pressure is 10^{-4} microbars. The displacement is thus 10^{-10} centimeters, considerably less than the diameter of a hydrogen molecule (2.34×10^{-8} cm.). In addition, the range of intensity the ear is capable of distinguishing is 10^{14} (140 dB). In terms of time, the range represents a ratio of one second to 3.2 million years; in terms of area, the ratio of one square yard to the total surface of the earth.[11]

B. NONAUDITORY PHYSIOLOGICAL RESPONSE

1. Physiological changes

Loud sounds can cause an arousal response in which a series of reactions occur in the body. Adrenalin is released into the bloodstream; heart rate, blood pressure, and respiration tend to increase; gastrointestinal motility is inhibited; peripheral blood vessels constrict; and muscles tense. On the conscious level we are alerted and prepared to take action. Even though noise may have no relationship to danger, the body will respond automatically to noise as a warning signal. Not only might there be harmful consequences to health during the state of alertness, but research also suggests effects may occur when the body is unaware or asleep.

2. Activation of response

Impulses from the brain activate centers of the autonomic nervous system which trigger a series of bodily reactions as part of a general stress response. Systems that may be affected include the glandular, cardiovascular, gastrointestinal, and musculoskeletal systems.

3. Short-term exposure

It is generally believed that there is no risk from short-term exposure to noise since the body has a chance to recover. A little stress, as many people will attest, may be beneficial. There may be exceptions to the above statement.[12]

4. Long-term exposure

It is possible that repeated or constant exposure to noise can contribute to a deterioration in health. Whether or not environmental or industrial noise by itself can lead to chronic disturbances is hard to determine since there are so many other stresses to which people are exposed.[13] This research is difficult to conduct and little has been done in this area, but research is accumulating which suggests a relationship between long-term noise exposure and stress related health effects, particularly those related to the cardiovascular system.

5. Stress effects of noise

Stress can be manifested in any number of ways, including headaches, irritability, insomnia, digestive disorders, and psychological disorders. Workers who are exposed to excessive noise frequently complain that noise just makes them tired.

Quite a few field studies have been done on workers in Europe, examining the relationship between noise and illness. In these studies, noise has been related to the following.

General morbidity (illness)

Neuropsychical disturbances

- headaches
- fatigue
- insomnia
- irritability
- neuroticism

Cardiovascular system disturbances

- hypertension
- hypotension
- cardiac disease

Digestive disorders

- ulcers
- colitis

Endocrine and biochemical disorders

There is a need for additional laboratory replications of these potentially important findings.

C. SLEEP DISTURBANCE

Sleep disturbance is one of the major causes of annoyance due to noise. If it becomes a chronic problem, sleep disturbance may potentially lead to health disorders.[14] Noise, of course, can make it difficult to fall asleep. Noise levels can create momentary disturbances of natural sleep patterns by causing shifts from deep to lighter stages. Noise may even cause awakening which the person may or may not be able to recall.[15]

A person whose sleep has been disturbed severely may feel lethargic and nervous during his waking hours and may be unable to perform at his usual level of efficiency.[16]

1. Effects of noise level

Generally, the higher the noise level the greater the probability of a response.[17] Thiessen found that there was a 5 percent probability of subjects being awakened by peak levels of 40 dB (A-weighted level) and a 30 percent probability at 70 dB.[18]

2. Effects of sleep deprivation

Sleep after prolonged periods of sleep deprivation consists of increased time in stages Delta and REM. This causes an increase in the thresholds for arousal and stage change.[19] Overall, sleep-deprived individuals require more intense auditory stimuli to awaken than do normally rested persons.[20]

D. COMMUNICATION INTERFERENCE

The indirect effects of speech interference are:

Disturbance of normal domestic or educational activities

Creation of an undesirable living environment

Safety hazards

A source of extreme annoyance

1. Social effects

For certain individuals who live in noisy areas, the adoption of a lifestyle that is devoid of communication and social interaction can result. If noise interferes with their communication, they stop talking, change the content of their conversations, talk only when absolutely necessary, and frequently repeat themselves.[21]

2. Safety

Masking of warning signals and directions by other intrusive sounds can be hazardous. For example, an airline pilot's reception of an air traffic control message can be affected by too much background noise. A missed warning in a noisy steel mill can result in an accident, injury, or even death.[22]

3. Methods of characterizing noises

- The Articulation Index (AI), a complex measure which accounts for the differences in masking capabilities of frequencies in background noise.
- The Speech Interference Level (SIL), an arithmetic average of the octave-band sound pressure levels of noise that affect the major speech frequencies (octave band SPL's are centered at 500, 1000, 2000 Hz).
- A-weighted sound level, which reflects the sensitivity pattern of the ear's response to noise and speech.[23]

A-weighting gives the greatest weight to those components of noise that fall in the frequency range where most speech information resides. It gives less emphasis to noise in the lower frequency (500 Hz or lower) range than does the overall sound pressure level.

E. PERFORMANCE INTERFERENCE

1. Determinants of interference

In any particular case, at least four factors should be kept in mind:

Characteristics of the noise

Characteristics of the task

Aspects of performance considered important

Individual differences

In general, noise is more likely to reduce the accuracy of work rather than the total quantity and it affects complex tasks more than simpler ones.[24] As the noise level increases, both reaction times and numbers of errors increase. These effects are more pronounced for complex tasks than for simpler tasks. In fact, for some simple tasks, noise may enhance performance.

2. Noise levels most likely to be detrimental to performance are:

Continuous noise levels above 90 dB (A-weighted)

Levels less than 90 dB (A-weighted) if they have predominantly high frequency components, are intermittent, unexpected, or uncontrollable.[25]

3. Intermittency

When a noise occurs in a random, intermittent or unpredictable fashion, errors tend to increase, and greater effort is required to maintain concentration. Unpredictable noise may lead to breaks in concentration that are followed by compensating increases in the work rate. Thus, the overall rate of work may not be affected, but the variability of the work rate may be.[26]

4. Controllability

Noises that are unpredictable or randomly intermittent tend to be associated with greater decrements in performance than in continuous noise. These decrements may in part be explained by the fact that these noises are perceived by the individual as being unpredictable.

Recent research suggests that exposure to unpredictable noise may result in performance decrements which occur <u>after</u> the noise has ceased (after-effects).[27]

5. Intensity

High-intensity noise such as jet engine noise in close proximity is reported to cause nausea, vertigo, uncoordination, fatigue, and mental confusion. These effects are attributed to vestibular stimulation and to reflexes elicited by vibration of the skin, muscles, and joints. Any of these symptoms can give rise to a reduction in performance efficiency.[28]

6. Frequency

In general, high frequency noises (above 2000 Hz) impair performance more than low frequencies of the same sound pressure level.[29]

7. Information content

The meaning of the noise is an important variable. Relevant and meaningful information is attended to, rather than ignored, thereby detracting from the task at hand.

8. Tasks affected by noise

Tasks that involve concentration, learning, or analytic processes

Tasks where an integral part of performance is speaking and/or listening

Tasks requiring fine muscular movements

Simultaneous tasks

Tasks which require continuous performance

Tasks including prolonged vigilance and few signals

Performance of any task that involves auditory signals

Tasks requiring attention to multiple channels [30]

Depending on the complexity of the task, noise may either improve or interfer with performance. Tasks that are mechanical or repetitive, and where average levels of performance are sufficient, will seldom be affected. Moderate levels of noise can produce beneficial arousal levels during monotonous tasks. Moderately difficult effort tasks seem to be unaffected by the noise. Highly complex tasks requiring attendance to a large number of cues, or to many cues in rapid succession, may be affected by noise at all levels of intensity.

II. SUBJECTIVE RESPONSE

A. MENTAL AND PSYCHOLOGICAL EFFECTS

Excessive noise exposure can bring about a wide variety of psychological responses or symptoms in the individual. A person may respond with anger, or experience symptoms such as anxiety, irritability, and/or general

emotional stress. Noise may negatively affect work performance because of reduced worker morale and motivation, or distraction and poor judgment may result from mental fatigue. [31]

B. CORRELATION TO MENTAL ILLNESS

Any correlation is still unclear. Studies have shown that residential areas exposed to high noise levels may have a higher incidence of mental illness among their residents, however the evidence is inconclusive. One study that examined admissions of residents, living near London's Heathrow airport, to a psychiatric hospital suggest that the prevalence of mental problems was higher in the population nearest the airport.[32] On the other hand, a Swiss study looking at the mental health status of residents near three Swiss airports found no significant relationship between minor psychiatric illness and noise exposure.

C. FACTORS

1. Physical

The physical attributes of noise that can affect an individual's subjective response include: apparent loudness or intensity, spectral shape, presence of discrete frequency components, abruptness or impulsiveness, intermittency, duration, and temporal variations. [33]

2. Other

Among the factors that affect an individual's response to noise are contextual factors such as: the time of day, the activity interfered with, the ability to control the source, and the information content of the noise. Response may also be affected by personal factors such as previous experience with noise exposure or socio-economic and educational status. [34]

D. REACTIONS

1. Behavior change

People may either take direct physical actions or make indirect mental adjustments to cope with noise. For example, people may spend less time outdoors, keep their windows closed, take sleeping pills use earplugs, spend less time talking and socializing, or complain to government officials. On the other hand, they might direct their anger at a noise inward and blame themselves for being bothered by it. They may perhaps deny there is a problem and attempt to stop responding emotionally to it. They may even project their anger at a noise source to a person incidently associated with it. [35]

2. Anti-social behavior

Noise can cause people to exhibit such anti-social behavior as aggression and violence, though those people would not normally do so. Incidents that have been reported, for example, include a business executive shooting at nearby water-skiers, or a usually quiet, night clerical

worker shooting and killing a child playing outside his apartment. Both examples provide anecdotal illustrations of effects on behavior presumably due to noise.[36] There have also been lab studies which show that excessive noise may reduce social interaction, social responsibility, and verbal disinhibition, or diminish helping behavior, and increase aggressive response.[37]

3. Individual variation

Social surveys have indicated wide individual variations in response to noise. It appears that personality does play some part in a person's subjective response to noise, although the exact nature of the relationship is too complex to readily assess. Some studies have concluded that those with a fairly high level of empathy, intelligence, and creativity may be more sensitive to noise than most.

III. COMMUNITY RESPONSE

The HUD Annual Housing Survey (1975, 1976) indicates that noise is the most frequently cited undesirable neighborhood condition, surprisingly ranking higher than crime. Noise is often given as the reason for residents wanting to move from their neighborhoods.[38]

A. MEASUREMENT

1. Social surveys

Community response to noise is usually studied through social surveys. A number of social surveys have been conducted world wide to determine the extent of the noise problem as well as to assess the response of the people to specific noise sources. These studies attempt to predict, on an aggregate basis, the degree of annoyance or other effects that can be expected by the community at varying noise levels. The average response of the community is used because it is very difficult to predict the response of any given individual.

2. Complaints

Another way of assessing community response is through complaints and legal actions. However, many other economic, political, and social factors influence the filing of complaints. So the quantification of complaints cannot be used as definitive expressions of community response.

3. Other predictors

The Urban Noise Survey found that activity interference (of speech, sleep, etc.) is a good predictor of annoyance. Speech interference is one of the most widely perceived effects of environmental noise. Another predictor of community annoyance is population density. Higher population density areas generally have higher noise levels, thus the annoyance is greater.[39]

4. Factors in response

Social surveys have shown that the following factors may contribute to community noise annoyance.

1. Fear associated with activities of noise sources such as fear of crashes in the case of aircraft noise

2. Socioeconomic status and education level

3. The extent to which community's residents believe that they are being fairly treated

4. Attitude of the community's residents regarding the contribution of the activities associated with the noise source to the general well-being of the community

5. The extent to which residents of the community believe that the noise source could be controlled.[40]

B. URBAN NOISE SURVEY RESULTS

1. Relationship between noise level and annoyance[41]

Noise Level (L_{dn})	Percentage of Population Annoyed
55	7
60	12
65	17
70	23

2. "Normalizing" factors

In relatively noisy areas where the L_{dn} exceeds 60 dB people consider noise to be more obtrusive in the evening and night hours. People are more annoyed by noise in the summer, presumably because windows are open, and there may be additional noise sources such as air conditioners and lawnmowers. The results of the survey also show that people are more annoyed by noise indoors than outdoors.[42]

3. Major conclusions

Exposure to noise typical of many urban (non-aircraft and non-highway) environments produces widespread annoyance, speech interferences, and sleep disturbance.

A strong relationship was demonstrated between exposure level and the proportion of a community highly annoyed by noise.

The prevalence of speech interference is an especially good predictor of annoyance.

Population density is an important correlate of noise exposure.

The number of complaints about noise is a poor predictor of the prevalence of annoyance.

Demographic factors alone are relatively poor predictors of noise annoyance.

Freedom from noise exposure is a component of neighborhood satisfaction, and quiet is highly valued.

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NOISE ENFORCEMENT AND PUBLIC INFORMATION IN SALT LAKE CITY

Presented by:

Richard Ranck
Director
Bureau of Environmental Protection
Salt Lake City/County, Utah

The Salt Lake City-County Noise Control Program has experienced tremendous growth since it was first conceived in 1971. It has become one of the most active noise control programs in the country, encompassing the areas of stationary and vehicle noise enforcement, land use planning, and public education/information. During the past eight years the administration of the health department and local elected officials have supported the noise program through an increasing allocation of resources, both manpower and budgetary and by responsive legislative measures.

When Salt Lake area citizens began vocalizing their concern over increasing noise problems to local officials, the media responded with editorials calling for the recognition of noise as a serious threat to the health and welfare of Salt Lake residents. In 1972, after investigation by the Salt Lake Board of Health, the health department initiated a one-man noise control program under the direction of Richard B. Ranck, Jr., Director of the Bureau of Environmental Protection. In 1973, city and county ordinances were adopted and an active noise control program addressing the problems of stationary noise sources and vehicle noise enforcement began with the addition of two noise technicians. The program's response to over 1,500 noise complaints and vocalized citizen concerns, the issuance of over 4,500 citations to date for excessive vehicle noise and the cooperation of the Salt Lake City and County Police Departments have alleviated many of the acute noise problems.

Through stationary noise enforcement, nuisances such as early morning construction and garbage pickup have been greatly reduced. Each complaint concerning a stationary noise source is personally investigated by one of the trained staff members. The Salt Lake City-County Health Department's Noise Control Program boasts a near 100% compliance record to stationary noise complaints. Although violations of the noise ordinances are misdemeanors and punishable by fines up to $300.00 and/or up to a six-month imprisonment, the objective of the noise program is to achieve a more productive and restful community through voluntary compliance.

The vehicle noise program was designed to meet the objective of voluntary compliance. The health department furnishes noise-monitoring equipment and technicians to make the measurements. The Salt Lake City Police and Sheriff's Department furnish off-duty chase officers. When violators are stopped, they are advised what the allowable noise level is and notified that if the vehicle is brought into compliance and passes inspection, the noise control officer may recommend a dismissal of the citation.

Because the real solution to noise problems is recognized to be prevention, the noise program now reviews over 50 requests for zoning changes and conditional use permits per month and provides recommendations for planning. As rapid growth in Salt Lake continues the goal of maintaining a safe noise level is enhanced by allowing only noise-compatible land uses. Monitoring the noise level at

Salt Lake City Airport and the surrounding residential areas is an example of a preventive measure to help maintain the present high quality of life experienced in Salt Lake City.

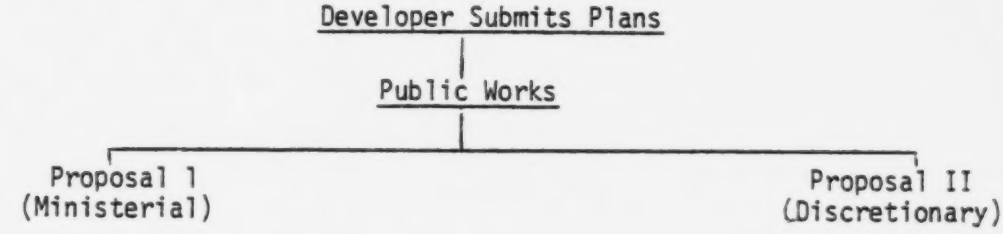
In order to maintain an ongoing, successful noise control program that has the support of local government officials, the business community, and the citizenry, public education must be an integral part of the program. A total public awareness strategy has been developed for Salt Lake City that will provide information on the health and welfare effects of noise prollution and promote noise control efforts in Salt Lake City. Generating media interest, involving community organizations in noise control activities, developing local program brochures, introducing a noise curriculum in the public school system, posting "noise ordinance enforced" signs throughout the city and hosting an annual "Quiet Week" are all part of the strategy to increase public awareness.

OUTLINE FOR NOISE PRESENTATION IN TUSCON, ARIZONA ON APRIL 9 and 10, 1980
BY HARRY SEN, INDUSTRIAL HYGIENIST

Sacramento County has been in the Noise business for nearly 10 years, and in 1975/76 both the Noise Element and Ordinance were enacted to support the program. This enactment provided an additional man and $30,000 (equipment) to the program. We have a total of two (2) men working 90% in Noise Control and 10% in Occupational Health.

The Noise program is divided into two sections -- Enforcement and Land Use. Land Use is the primary emphasis. Our office assists subdividers, contractors, acoustical consultants, planners and building department officals by providing direct service in identifying the noise problem which includes limited sound studies and mitigative measures to comply with the Noise Element, the Noise Ordinance, and Federal and State legislations. Should Jarvis II become law in California, existing program priorities may change.

A brief flow chart of how this Land Use process functions in Sacramento County is as follows:



Proposal I (Ministerial)

Should the architectural plans and use conform to initial zoning, a building permit is issued without any further approval from the Zoning Administrator, Subdivision Review Committee, Planning Commission, and Board of Supervisors.

Noise Control:

1. Title 25, California Noise and Insulation Act --- interior standard of 45 dB CNEL for multiple housing.

2. Building Department enforces Title 25, and the noise element. Currently our office is preparing a testing and review procedure for implementation of the compliance program. The State office of Noise Control recently completed architectural STC Manual to assist in the review process - publication pending. We are hopeful that this program will be executed within six months.

Proposal II (Discretionary)

Should architectural plans and use not conform to initial zoning, the procedures are as follows:

1. All projects are reviewed under the California Environmental Quality Act --- enacted in 1970.

OUTLINE OF NOISE PRESENTATION

Types of Discretionary proposals:

a) rezone
b) variance
c) use permit
d) development permit

(The EIR section of the Planning Department screens for our review all noise impacted projects.)

e) subdivision
f) parcel map - division of land in more than four lots.

(All parcel map split and subdivision proposals are reviewed with input by our department. Attached is a copy of such activities. Ninety percent (90%) of the current reviews are impacted by transportation noise sources -- highway, railway, airport, and waterways.)

Recommendations made from our office are generally well received by the Subdivision Review Committee, Planning Commission, City Council, and Board of Supervisors. There have been denials, extensive modifications of plans and mitigative measures imposed based on our recommendations. The final approval on noise impacted projects requires our final approval.

Slide presentation depicting before and after projects relating to noise control in the land use process. In addition, examples of noise control methodology for both land use and enforcement controls which includes:

a) various shielding methods (sound walls, etc.)
b) architectural design and orientation of buildings
c) insulation of buildings
d) mechanical noise control enclosures
e) various types of noise contours

POPULATIONS EXPOSED TO NOISE: THE ROLE OF THE CITIZEN AND THE RESPONSIBILITY OF GOVERNMENT

Barbara Sherman
Community Noise Adviser
Tempe, Arizona

The title of my speech is long and wordy, probably because the process of developing the ideas for my comments today were lengthy and circuitous. I've been asked to share some ideas with you about the role of the citizen in the environmental noise area. In particular, I've been asked to share some of my own experiences with you. I'll start with this. But my title is populations exposed to noise. The reason for this heading is that last fall, I proposed a relook at the 1977 Urban Noise Survey contracted by the Environmental Protection Agency to Bolt Beranek and Newman. Both the EPA and BBN were kind enough to supply me with the raw data from this study so that I could explore an idea. I felt that the study might possibly answer some questions I had about the relationship between income level, noise level, annoyance and complaint levels. It had seemed in the Phoenix metropolitan area that noise levels are concentrated in low income areas but that complaints and responsive government action are concentrated in higher income areas. I have been asked to discuss my findings from the Urban Noise Survey and will also share some of my experiences in Phoenix.

Finally, my comments are a challenge to government employees to be responsive to citizen problems. In other words, I will share with you some of my deep frustrations with the lack of responsiveness I see in some governments to noise problems.

First, the role of the citizen and my experiences as a citizen activist. The American style of government is advocacy. Unless some one advocates attention to and solutions for a problem, it is likely that the problem will become part of the status quo. The principle role of the citizen in an advocacy

system is to point out problems. Thus, in the environmental noise field citizen complaints are very important. I presume that most of my audience consists of government officials who respond to complaints, among other things. For the majority of citizens, activity stops with the filing of a complaint. For this reason it is important that government's heed complaints and act to solve problems addressed and raised in complaints. I also serve in the capacity of taking noise complaints. It is very frustrating. Sometimes there is little that I can do in my position but be pleasant in response.

Those of us who take complaints need to be reminded of the costs to citizens of complaining. People do not want to be labeled as "complainers," "naggers",someone who is always "bitching." It is psychologically and sociologically sometimes very difficult to complain. The persistence that is often necessary to register a complaint, to have a problem heard, is often overwhelming. I have had people call me after they have been referred to no less than eight numbers before they reach mine. Sometimes months of serious effort is necessary to reach the right person to register a complaint and hopefully solve a problem.

On the other hand, sometimes the only way you know that a problem exists is from complaints. But how few people actually complain about serious noise problems? Complaints represent the tip of the iceberg.

I realize that improvements need to be made by citizens as well as government officials at the complaint level. I find myself in the situation of advising citizens how they should and should not complain and then also advising government agencies how they should and should not respond to citizen complaints. Needless to say that endears me to all parties.

The role of the citizen extends beyond complaints. I describe myself as a "citizen activist." In that capacity I've conducted phone and petition campaigns, researched problems, spoken at public hearings, organized committees, chaired committees, etc. With specific reference to noise I've worked on the Tempe noise ordinance, lobbied for aircraft noise legislation at the state

legislature, represented the City of Tempe at various noise related conferences, and represented the City of Tempe on the Phoenix Sky Harbor Noise Abatement Committee for six years.

As a result of these experiences with environmental noise, I've also had the opportunity to work as a planner to evaluate the noise situation in Maricopa County and serve as a noise consultant on a municipal airport environmental impact study. I now also represent the City of Tempe as a Community Noise Adviser for the EPA ECHO program.

I like to think of myself as a "successful" citizen activist. The key to what success I've had has been the help and support of responsive government. My first interaction with government was interesting and positive. Most citizens are not as lucky as I.

It is critically necessary that governments respond to complaints in terms of solving problems. Allow me to share some of my frustrations with the lack of response I find in the Phoenix metropolitan area before I discuss the Urban Noise Survey.

The Phoenix area provided my initial interest in the national noise study and my question of the importance of income level in determining reactions to noise levels.

The premise behind my frustration is that subjective nuisance is not the real criterion of noise problems. Objective noise levels can be related to health, safety and the public welfare. These objective levels, especially those that exceed the criterion level for health, should determine where we concentrate our noise efforts. In other words, we should work to solve objective noise problems not to satisfy the squeaky wheel. Government officials should have the responsibility to look beyond complaints to find out what and where the problems are and work toward solving them. This is not what has been happening in the Valley of the Sun.

Phoenix citizens west of Phoenix Sky Harbor International Airport have overflights at noise levels that exceed health criterion levels. A 1977 noise contour study showed that 207 acres of residential land plus thousands of people are exposed to levels above the 70 Ldn. Thousands of people are exposed to noise levels above the health criterion level - above levels that are safe from hearing loss and other noise related health effects.

Tempe abuts Phoenix Sky Harbor on the east. In Tempe almost all the population lives within contour levels that protect the health of the citizenry. Scottsdale, north of Tempe, has overflights from Phoenix Sky Harbor Airport at somewhat reduced levels from Tempe. Scottsdale also has a municipal airport that currently impacts citizens at levels below the health criterion level.

This is the noise situation briefly. What is the complaint situation? The popular concensus among government agencies is: Phoenix citizens do not complain about Phoenix Sky Harbor traffic; Tempe citizens complain sporadically; and Scottsdale citizens complain frequently. Complaint levels rise as income levels rise. But noise levels decrease as income levels rise. So the people exposed to the highest noise presumably complain the least, and the people exposed to the lowest noise complain the most. Income levels of the citizenry are low in Phoenix, moderate in Tempe, and highest in Scottsdale. My frustration is that government response levels are also negatively correlated with income level. This fact is a major cause of the persistence of some significant and grave noise problems in the Phoenix area.

Looking at complaints we find that government agencies have used them as an indicator of the seriousness of noise problems. But government agencies have not kept any records of complaints from Phoenix citizens. It is easy to dismiss complaints when there is no record of them. I hear a different story about the frequency of complaints from citizens than I do from goverment officials in Phoenix. I have a friend who recently wrote a clever letter to the FAA telling

them about the excessive noise from Phoenix Sky Harbor aircraft at his home. He wrote to say that it would be a great nuisance for him and for the FAA if he called them to register every complaint. His letter was a complaint about every flight over his house -- all departing and arriving commercial aircraft flying over Phoenix are very loud at his house. Every plane stops conversations, disturbs thought, sleep, etc. Unfortunately, this letter will probably be registered as one complaint, if at all, rather than a complaint for every commercial flight over Phoenix.

In contrast to Phoenix, government agencies keep records of complaints for Tempe. Why? The squeaky wheel. These records are used as indications of problems. They are not the best of indicators - citizens get tired of complaining. They complain for a while and then decide what's the use. Complaints in Tempe refer generally to lack of compliance with an established noise abatement procedure. Scottsdale citizens are complainers about Phoenix Sky Harbor traffic and Scottsdale Municipal Airport traffic. At Scottsdale Municipal Airport, an aggressive program of meeting with citizens and discussing problems was initiated years ago to deal responsively with noise problems. In summary, these are the different styles of addressing noise problems in the Phoenix area. As income levels rise, responsiveness increases but noise problems decrease. Governments should act to solve problems not grease squeaky wheels. Governments should work first where the needs are greatest. Government efforts should be concentrated on solving health noise problems first. The corner stone of noise ordinances and other programs in the new environmental noise movement is quantified objective noise levels related to health, safety and welfare criteria. Governments should respond according to those levels rather than to subjective criteria such as the income level of the complainer and the education or presentation of the complainer.

Turning to the Urban Noise Survey, when I first received a copy of the Urban Noise Survey, the text and data suggested that the Phoenix phenomenon

might be more widespread. The aggregate data suggested that more complaints came from higher than lower income level neighborhoods.

The Urban Noise Survey was a national study conducted by BBN for EPA of neighborhood noise at 24 sites in 7 cities. Noise measurements were taken at the same time a survey was conducted in each neighborhood. Over 2000 individuals were interviewed in areas selected to avoid significant aircraft and traffic noise.

The study found that lower income neighborhoods had higher noise levels, that high socio-economic level respondents suffer less noise than lower income respondents. Yet 7% more of the high income respondents complained about neighborhood noise. The Urban Noise Survey found a negative correlation between income level and annoyance with noise. My analysis of the raw data show no significant difference for annoyance and complaints in terms of income level. Low income persons have similar complaints and concerns, or annoyance, with noise as higher income individuals. There is an inverse or negative relationship between income and noise level in the national survey. This shows that quiet costs. Neighborhood satisfaction was also found greater among higher income respondents from quieter areas.

What the national survey does not tell us is whether or not the government responds to complaints and problems in terms of income level instead of problem magnitude. The purpose of my comments today is, in large part, to challenge you not to make that mistake yourself.

I would like to think that income level is not the criteria of responsiveness in the Phoenix area but the facts seem to get in my way. If my only concern were in the area of complaints, as previously mentioned, I could be accused of making a mountain out of a molehill. My concerns are more complicated and serious.

I would like to talk briefly about the complications of land use

compatibility and noise impacted residential areas. There is a concensus among noise officials and government agencies who have addressed the problem that when noise levels are very high we should not insure housing in the area, we should discourage residential usage, and we should even move the residents away from the area. There are long term secondary impacts to these policies. Failure to insure is, in essence, a red-lining of an area for not only federal insurance but also bank loans. This has economic impacts on the neighborhood. Relocation of populations from noise areas also has secondary impacts. There is an extensive literature on relocation (urban renewal) that says we may be doing a disservice to the people in the guise of helping them. Do we know what we are doing when we relocate people from their homes, friends, social support systems? I ask these questions rhetorically because they bother me. Phoenix Sky Harbor is in the process of a relocation project that will relocate approximately 6000 people, almost 2000 families, over a 10-year period. As a friend said -- relocation should be the last step in a noise abatement program! The problem in Phoenix is that it is the first step. The only noise abatement program initiated to solve Phoenix citizen problems has been the extension of the north runway - this allows a tremendous increase in traffic so that two runways can now produce more noise than ever before and increase the impact over two sets of people instead of concentrating it on one.

Phoenix citizens are not represented on the Phoenix Sky Harbor Noise Abatement Committee. Noise abatement procedures have been proposed and implemented and are in the process of revision for Tempe and Scottsdale who have representation on the Phoenix Sky Harbor Noise Abatement Committee. The relocation program puts the cart before the horse. The government has been less than responsive to Phoenix citizens. In general, federal government policies have not served Phoenix citizens. Government insurance and bank policies have insured the deterioration of the neighborhood. Property value reimbursements may or

may not cover the costs of a new house in today's market. The hue and cry from the citizenry on this matter suggests that the costs are much too little. This is not at all hard to understand given today's housing prices and interest rates. There are serious problems with relocation -- even at its best.

Some individuals in Phoenix are without fault in their concern, empathy and devotion to helping Phoenix citizens through this crisis. Others are not. I have heard an important official dismiss a citizen's comment because it did not support the perceived concensus that the relocation was a positive good. A young woman made an eloquent statement at a hearing to the effect that some people chose to stay in the relocation area -- she asked if it would be possible for citizens to have that choice and for some of the relocation money to be used for redevelopment in the area? This is but one example of where and when city officials and employees have failed to listen to the citizenry in Phoenix and have not addressed their problems.

I detail these problems to you because it is important that we all respond to citizen problems and attempt to solve them. It is also critical that in our solution we continuously listen to the people. How else can we catch our potential mistakes?

Citizen participation is critical to noise control and other programs. It is necessary to call attention to the problems and keep us moving toward appropriate solutions. If we forget we are attempting to solve citizen problems and fail to keep track of how well those solutions are working, we may fail. Hopefully citizens will continue to keep us informed and we will be responsive enough to encourage citizen information. Working together with citizens we can find appropriate solutions.

COMMUNITY NOISE WORKSHOP

TUCSON, ARIZONA, APRIL 9-10, 1980

"How Can EPA Be Of Assistance"

Richard Procunier, Regional Noise Program Chief

The Quiet Communities Act of 1978 greatly augments the responsibilities of the U.S. Environmental Protection Agency in the area of assistance to States and communities in controlling noise. This act imposes no duties or responsibilities on States and localities in the area of noise control. Instead, it directs EPA to assist States and communities to carry out their own locally-developed programs to control noise. EPA is authorized to provide financial assistance to States and localities in four general areas:

Identification and quantification of noise problems.

Development of the capability of States and communities to control noise, including the purchase of initial equipment and dissemination of information to the public.

Noise abatement planning around major transportation sources including airports, railroads, and highways.

Demonstration and evaluation of abatement techniques.

In addition to financial assistance, the statute directs EPA to expand its efforts in the area of public education and information, to inform the public of the effects of noise and what can be done to control it. This will include noise information for schools, civic organizations, public officials, and the general public. To assist in public request for noise educational and informational materials, tthe National Information Center for Quiet has been established.

The Quiet Communities Act also directs EPA to conduct research on the effects of noise control technology and the economic impact of such technology.

Older Americans are currently working in urban areas as trained community noise counselors. They recommend solutions to local noise problems, meet with students' organizations and local officials, and disseminate

information to the public, and act as a community noise ombudsman.

The ECHO (Each community Helps Others) program, working with the National Leagues of Cities, appoints noise advisors to advise other communities on a volunteer basis with their special expertise in noise control. The Region's current ECHO community noise advisors include Jim Dukes of San Diego, Chuck Nay, Airport Noise Advisor, Torrance Airport, Barbara Sherman, Advisor from Tempe, Arizona, and Tom Anamizu of Oahu. An example of a recipient community was Tempe, Arizona, which was assisted by Jim Dukes of the San Diego Noise Control Administrator. The Regional noise control program includes the support of a Regional Center for a Quiet Environment, which will be sponsoring workshops in each regional State every other year. We are also providing encouragement to start a quality assurance program where local communities could be assured of their sound level measurements. We also have a special project to identify noisy aircraft that violate single event levels. This has been carried out at Torrance Airport, and is planned for another major air carrier airport.

Important coordinative roles for environmental noise programs are best done using key Counties as primary actors.

A County Noise Advisor can offer technical advice, give direct assistance to incorporated communities within the County, and coordinate requests to EPA. We expect to discuss these roles further, including development of agreements between counties and incorporated communities, and an activity analysis of existing programs. The Maricopa County Noise Advisor is Michael Sparkes and the Pima County Noise Advisor is Bailey Battiste.

PRACTICAL HINTS FOR NOISE CONTROL

Vincent Salmon

Presented at Conference on Community Noise Control: Measurement and Regulation: Tucson, Arizona, April 9-10, 1980.

Topical Outline

1. Noise, one of many stressors. Reactions depend on level, time of day, individual sensitivity, context, feelings of helplessness or frustration association with activities undesired by listener (opposite political or lifestyle orientation), association of noise with danger, livelihood. Most control regulation depend on assumption of reasonable person of normal sensitivities.

2. Criteria for determining normalcy of reaction:
   2.1 Are complaints widespread or sparked by a few?
   2.2 What is complaint history of people involved?
   2.3 What is local political situation?
   2.4 How do measurements and resulting predictions relate to actual complaint situation? Normal expectations are:
      2.4.1 If C is % of population complaining (letters, phone calls), and H is total % highly annoyed but not all complaining, then $H = 12.3\sqrt{C} + 4.3$
      2.4.2 Expected reactions

	L_{dn}	C%	A%
None	55	1	17
Complaints, threats of action	61	2.3	23
Vigorous actions	71	11.2	45

3. Ear as best instrument
   3.1 Locate source by cupping hands back of ears, rotating head.
   3.2 Walkaway test for level: two people in noise outdoors, to determine acceptability for ordinary housing; one person reads in a normal tone while other backs away to determine position at which sentence intelligibility is lost:

Distance	Evaluation
Less than 7 ft	Clearly unacceptable
7 to 25 ft	Normally unacceptable
26 to 70 ft	Normally acceptable
Beyond 70 ft	Clearly acceptable

   3.3 Intermittency and presence of impacts, impulses
   3.4 Frequency content; describe as rumble, roar, rush, hiss; presence of pure tones.

4. General means of control
   4.1 Usually control at source, along path: control at receiver implies protection construction or hearing protection (plugs, muffs).

4.2 Modalities: psychological, physical. If criteria of two above suggest that complainant is not likely to be a reasonable person of normal sensitivity, often only physical removal or complete shutdown of offending source will suffice. If normal, use planning, with evaluation of opposing forces of tax base vs value of quiet. Then physical modalities.

4.3 Physical means of control: For either airborne or solidborne sound, isolate to reduce transmission along path, or change sound into heat by absorption. Airborne isolation by barriers, enclosures: materials are heavy, impervious. Absorb airborne sound by selected absorbents: materials are lightweight, porous. Use proper material. Might need consultant help.

4.4 Consultant evaluation: ask about training, membership in professional societies, experience, references to clients, registration as professional engineer, association with sale of acoustical materials.

5. Examples of sources, controls. LUP = land use planning; TOU = time of use; NEC = no easy control.

5.1 Stationary sources, including those moving about on a site of restricted area:

Source	Controls
Sports: races, stadiums	NEC; barriers may help; TOU; location
Playgrounds, games courts, parks	Location, barriers: NEC; TOU
Dogs	Keep indoors; debark; water training; electroconditioning collar
Cats	NEC; spay, neuter
Rooster	Eat
Music	Location outdoors; TOU. Indoors, isolated room for practice, performance (discos); TOU.
Discos	Mufflers, TOU. Quiet machines
Yard care machines	NEC. Mufflers, lined tunnel for feed
Composter, wood chopper	LUP; TOU; barriers, sound traps on fans
Car wash	
Construction machines	
Piledriver	TOU: barrier skirts: muffler; sonic piledriver
Jackhammer	Quiet machine; muffler; internal damping; TOU
Bulldozer, etc	Quiet machine; muffler; TOU
Air compressor	Quiet machine; muffler; enclosure
Helicopter (for lifting)	TOU; NEC
Sewage disposal plant	LUP; enclosure; mufflers
Noisy manufacturing plants	LUP; enclosure; barriers; TOU
Body shop	LUP; TOU; protective construction
Outdoor transformer	Barrier; semi-enclosure; quiet fans, sound traps on fans
Roof airconditioning	Quiet machines; enclosure or barrier; sound traps; roof parapets

Sources	Controls
Cooling tower	Quiet fans; barrier; orientation
Household appliances	Quiet devices; absorption; damping
Firing ranges	Enclosure; barriers; shooter must wear hearing protection
5.2 Moving sources	
Airport operations	LUP, enforced; TOU; use of SENEL of identified aircraft to determine landing fee; modify dwelling by protective construction
Vehicular traffic	Enforce regulations; use ear to cite for excessive noise during operation, as equipment violation, to be cleared if compliance shown at test station
Railroad classification yards	LUP; TOU; quieter retarders; barriers
Railroad - over the road	TOU; barriers; quieted locomotives; track maintenance; control of use of whistle
Water skiing	TOU; quieter outboard motors
Snowmobiles	Quiet machines; LUP; mufflers

VEHICLE NOISE ENFORCEMENT

Presented by:

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1.2 History of Legislation

1.2.1 During the early 1940's, the California Legislature became concerned about truck and passenger car noise; this resulted in the purchase of a sound level meter by the California Highway Patrol. Attempts to use the meter to support arrests for excessive noise were generally unsuccessful because standards had not yet been established.

1.2.2 In the early 1950's, the American Trucking Association made a number of muffler tests using a standard sound level meter. During this same period, the Automotive Manufacturers Association adopted a 125 sones limit for all models of trucks. It was anticipated that all future production vehicles would comply with this requirement. 125 sones is compared to an average of 85 dB(A) at 50 feet. However, there were no meters that read directly in sones and the process of determining compliance was time-consuming and was never used for enforcement.

1.2.3 Attempts were again made by the California Legislature in 1961, 1963 and 1965 to establish noise limits for vehicles. Finally, in 1967, Vehicle Code Sections 23130 and 27160 were enacted and established maximum permissible noise limits for vehicles operating on the highway and for new vehicles. Regulations on vehicle noise measurement procedures were adopted by the California Highway Patrol in 1968. Also in 1968, the Department commenced testing new vehicles for compliance with the standard. In the

Spring of 1969, a full-time noise enforcement program was started in each of the Patrol's six zones. Concurrent with these efforts, several other states were attempting to establish noise standards. The State of New York adopted the first on-highway noise enforcement standard; however, the requirement applied only to trucks traveling at 35 mph and was unenforceable. Since then, their standard has been rewritten and now agrees with California's law. Many other states have followed California's lead and have adopted similar noise standards.

1.2.4 The U.S. Environmental Protection Agency has developed noise standards for heavy trucks. The U.S. Department of Transportation, Bureau of Motor Carriers, has adopted the EPA procedure and is doing some enforcement.

1.2.5 In 1973, the California Legislature added sections to the Vehicle Code requiring the Highway Patrol to establish a muffler certification program. This legislation was brought about by complaints from the public that mufflers were being sold which, when installed, produced excessive noise and made the vehicle illegal to operate.

1.3 Noise Laws Paraphrased from the Vehicle Code

1.3.1 Operational Standards for Vehicles On-highway and Off-Highway

(a) Section 23130. No person shall operate a motor vehicle in such a manner as to exceed the following statutory noise limits:

(1)	Heavy Trucks, 10,000 lbs. GVW or more:	86 dB(A) in speed zones 35 mph or less,
		90 dB(A) in speed zones over 35 mph.
(2)	Motorcycles, 15 GBH or more:	82 dB(A) in speed zones 45 mph or less,
		86 dB(A) in speed zones over 45 mph.
(3)	Other Motor Vehicles:	76 dB(A) in speed zones 45 mph or less,
		82 dB(A) in speed zones over 45 mph.

(b) Section 23130.5. The noise limits within a speed zone of 35 miles per hour or less on level streets with a grade not exceeding plus or minus 1 percent shall be:

(1)	Heavy Trucks, 6,000 lbs. GVW or more:	82 dB(A)
(2)	Motorcycles, 15 GBH or more:	77 dB(A)
(3)	Other Motor Vehicles:	74 dB(A)

(c) Section 27150. Every motor vehicle shall at all times be equipped with an adequate muffler properly maintained to prevent any excessive or unusual noise, and no exhaust system shall be equipped with a cutout, bypass, or similar device.

(d) Section 27150.1. No person engaged in the business of selling exhaust systems or parts for vehicles less than 6,000 lbs. GVW shall sell systems or parts which are not of a certified type.

(California Administrative Code, Title 13, Section 1051)

(e) Section 27150.2. The commissioner shall adopt regulations setting standards for the certification of vehicular exhaust systems.

(f) Section 27151. No person shall modify, repair or replace the exhaust system of a motor vehicle in a manner which will amplify or increase the noise emitted by the motor of such vehicle, above that emitted by the muffler originally installed on the vehicle and the original muffler shall comply with all of the requirements of this chapter. No person shall operate a motor vehicle with an exhaust system so modified.

(g) Section 38365. Every off-highway motor vehicle shall at all times be equipped with an adequate muffler in constant operation and properly maintained so as to meet the requirements of Section 38370, and no muffler or exhaust system shall be equipped with a cutout, bypass, or similar device.

1.3.2 Standards for New Vehicles

(a) Section 27200. The Department of Motor Vehicles shall not register a new motor vehicle which produces a maximum noise exceeding the applicable noise limit.

(b) Section 27201. The noise limit of 92 dB(A) shall apply to any motorcycle manufactured before 1970.

(c) Section 27202. The following noise limits shall apply to any motorcycle, other than a motor-driven cycle, manufactured:

(1)	After 1969, and before 1973	88 dB(A)
(2)	After 1972, and before 1975	86 dB(A)
(3)	After 1974 and before 1981	83 dB(A)
(4)	After 1980 and before 1986	80 dB(A)
(5)	After 1985 and before 1990	75 dB(A)
(6)	After 1989	70 dB(A)

(d) Section 27203. The noise limit of 82 dB(A) shall apply to any snowmobile manufactured after 1972.

(e) Section 27204. The following noise limits shall apply to any motor vehicle with a gross vehicle weight rating of 6,000 pounds or more manufactured:

(1)	After 1967, and before 1973	88 dB(A)
(2)	After 1972, and before 1975	86 dB(A)
(3)	After 1974, and before 1978	83 dB(A)

(f) Section 27204.5. The noise limit of 80 dB(A) shall apply to any motor vehicle with a gross vehicle weight rating of 6,000 pounds or more, but not more than 8,500 pounds, manufactured after 1977.

(g) Section 27205. The following noise limits shall apply to any motor vehicle with a gross vehicle weight rating of more than 8,500 pounds manufactured:

(1) After 1977, and before 1982 ..... 83 dBA
(2) After 1981 ..... 80 dBA

(h) Section 27206. The following noise limits shall apply to any other motor vehicle, not specified in this article, manufactured:

(1) After 1967, and before 1973 ..... 86 dBA
(2) After 1972, and before 1975 ..... 84 dBA
(3) After 1974 ..... 80 dBA

(i) Section 27207. No motor vehicle with a gross vehicle weight rating of more than 10,000 pounds and equipped with an engine speed governor shall produce a sound level exceeding 88 dBA, measured on an open site at a distance of 50 feet from the longitudinal centerline of the vehicle, when its engine is accelerated from idle with wide open throttle to governed speed with the vehicle stationary.

(j) Section 38370. The Department of Motor Vehicles shall not identify a new off-highway motor vehicle subject to identification which produces a maximum noise exceeding the following noise limit at a distance of 50 feet from the centerline of travel under test procedures established by the

Department of the California Highway Patrol.

(1) Any such vehicle manufactured before January 1, 1973 ..... 92 dB(A)

(2) Any such vehicle manufactured on or after January 1, 1973, and before January 1, 1975 ..... 88 dB(A)

(3) Any such vehicle manufactured on or after January 1, 1975 ..... 86 dB(A)

2. INSTRUMENTS

2.1 Introduction to Sound Level Meters

2.1.1 The sound level meter is essentially a high-quality microphone whose electrical output drives a highly sensitive volt-meter calibrated to read sound levels directly in decibels.

2.1.2 It operates from batteries that provide about 50 hours of continuous operation.

2.1.3 The attenuator control permits direct reading of sound levels over a range of 40 to 140 dB re 20 uN/m^2.

2.1.4 Vehicle sound level measurements are made with A-weighting and fast response. B- and C-weighting and slow responses are also included in some meters.

2.1.5 General Radio meters are used for field enforcement by the California Highway Patrol. B & K meters are used by CHP Engineering for new vehicle noise testing and other noise measuring work. Several makes of meters will be discussed here.

2.2 Introduction to Sound Level Calibrators

2.2.1 The acoustic calibrator fits over the microphone and, by means of a pre-determined sound with a known level, is used to set the meter to assure that the meter is functioning properly. Most calibrators are basically small speakers, driven by an oscillator, which set up a precise, repeatable sound pressure level (114 ± 0.5 dB re 20 uN/m^2) in an acoustic coupler.

2.2.2 Most calibrators produce a single 1000 Hz frequency and different sound levels. The calibrators are generally operated from one 9-volt battery (Burgess 2U6 or equivalent) which provides about 100 hours of operation.

2.2.3 The GR Type 1567 calibrator is a single frequency calibrator which produces 114 dB at 1000 Hz. The small B & K calibrator produces 90 dB at 1000 Hz. The Quest Model CA-12 produces 110 dB at 1000 Hz.

2.2.4 Some calibrators are different than the ones described here, and you should read the manufacturers' instructions before using the instruments. One GR calibrator has five frequencies but only 500 Hz is used to adjust the meter. A B & K calibrator, which is greatly different, uses a small motor and two pistons, and produces 124 dB at a very low frequency.

2.2.5 Because the designs of the microphone vary between manufacturers, calibrators should not be interchanged. Otherwise, the calibration may be incorrect and the microphone may be damaged.

2.3 Calibration of Sound Level Meters

2.3.1 With both the sound level meter and calibrator turned on, place the microphone coupling cavity over the microphone, and use the screwdriver calibration adjustment to set exactly the proper value on the sound level meter.

2.3.2 When this acoustic calibration is completed, the sound level meter is ready for operation.

2.3.3 This procedure will be explained further under instrument set-up.

2.4 Microphone Windscreen

2.4.1 The microphone windscreen reduces the effects of ambient wind noise and protects the microphone in misty or dusty environments.

2.4.2 Windscreens should always be used when making vehicle noise measurements.

2.4.3 They have virtually no effect on measurement accuracy.

2.5 Environmental Effects on Sound Level Meter and Calibrator

2.5.1 The sound level meters can be stored without damage (with batteries removed) out of the sun, over a temperature range of -40 to +140°F. They can be operated over a range of +15 to 120°F with minor correction factors required at the range extremes. (Temperatures in the trunk of a car can easily reach 160°F in the summer.)

2.5.2 The sound level calibrator has the same storage and operating temperature ranges. The same correction factors apply, so that the calibration point is true for all operating temperatures.

2.5.3 Both the sound level meter and sound level calibrator operate within specifications over a relative humidity range of 0 to 90%.

2.5.4 The sound level calibrator output varies with atmospheric pressure and its output is affected by altitude. A correction curve is included on Page 1-25. The sound level meter readings are true at a particular altitude when the meter is calibrated to the level shown on the curve for that altitude.

2.5.5 The sound level meter readings can sometimes be affected by strong magnetic fields. Keep measurement sites away from high voltage transmission lines and transformers.

2.6 Service and Repair Information

2.6.1 All instruments can be repaired or calibrated by returning them to the nearest factory service center. Repair or calibration should not be attempted at the local radio repair shops.

2.6.2 All units are covered by full parts and labor warranty for one year after date of original shipment and after each yearly calibration by the General Radio or the B & K repair laboratories.

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2.6.3 It is recommended that each instrument set receive preventive maintenance inspections and re-calibration once a year. This time can be expanded by sending only the calibrator in every other year; it should not exceed a two-year period.